

THE VENETIAN GALLEY OF FLANDERS: FROM MEDIEVAL (2-
DIMENSIONAL) TREATISES TO 21ST CENTURY (3-DIMENSIONAL) MODEL

A Thesis

by

COURTNEY ROSALI HIGGINS

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF ARTS

May 2012

Major Subject: Anthropology

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ABSTRACT

The Venetian Galley of Flanders: From Medieval (2-Dimensional) Treatises to 21st
Century (3-Dimensional) Model. (May 2012)

Courtney Rosali Higgins, B.A., University of Denver

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Nautical archaeologists and scholars often try to recreate how ships were built and maneuvered. Due to the delicate nature of older wooden vessels, there is often little archaeological evidence remaining to aid in these studies, and researchers must supplement what little they have with other resources, such as texts. By using computer programs to synthesize and enhance the information in the texts, scholars can better understand the vessel and explore questions that even hull remains may not be able to address.

During the High to Late Middle Ages, Venice was a key city for trade and commerce. Its location on the Adriatic Sea connected merchants throughout mainland Europe and the Mediterranean Sea. Since its founding in the low Middle Ages, Venice has been connected to the sea, leading to a long history of seafaring and shipbuilding. By the end of the Middle Ages, Venice had established several trade routes throughout the Mediterranean and Black Seas, and one long sea route into the Atlantic, to Lisbon, Flanders, and London.

Although no archaeological evidence of these galleys have been found, several contemporary texts describe the merchant galleys of the 15th century. Two of these texts, dating to the first half of the 15th century discuss the dimensions the galley: The book of Michael of Rhodes and the book of Giorgio “Trombetta” da Modone. Perhaps complementary copies of the same original, these texts contain enough information to reconstruct a 3-dimensional model of the galley of Flanders’s hull, in this case using off-the-shelf software ((Rhinoceros®). From this computer model the vessel can then be analyzed for volumetric information in order to better understand the hull capacity and how the ship was laden.

DEDICATION

I dedicate this thesis to my mother, Denise, and my late father Patrick, who both supported my love of archaeology and encouraged me to follow my heart when choosing a career.

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Most importantly I thank my mother, Denise, for her relentless support over these long years; my brother, Trevor, for always giving me a laugh when I most needed one; and my brother, Brendan, for editing this thesis and being the best listener I know. Finally, I could not have completed this journey without the patience and love of my husband, Dr.

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CHAPTER I

INTRODUCTION: GALLEY OF FLANDERS, A CASE STUDY

During the High to Late Middle Ages (the 13th to the 15th century) the Republic of Venice was one of the principal trading centers in the Mediterranean. Overseas trade was a key component to Venice's success. The city relied heavily on its talented shipwrights and the quality of the vessels they built. One specific vessel built during this period was the galley, a fast long ship powered by oars and sails, used by the Republic for both commerce and war. Among these, the galley of Flanders was especially important, as it traveled to some of the most important trading ports in the North of Europe. In this thesis, the galley of Flanders constitutes a case study using historical documentation and modern digital resources to study a vessel for which there is no existing archaeological evidence.

The power of Venice as a commercial empire during the High to Late Middle Ages was due in part to its establishment of trade routes throughout Europe, the Black Sea, the Middle East, and northern Africa. Venetian trade was conducted both over land and sea. Venice's commercial connection to cities throughout the Mediterranean provided a wide diversity of trade goods, as well as political allies.

This thesis follows the style of the *American Journal of Archaeology*.

From the beginning, Venice, a city established on a series of islets protected by a sandspit, had a history of building ships to maneuver the inner rivers, lagoon waterways, and into the outer sea. Venetians naturally used this knowledge to build ships suitable for overseas trade. The city's location between mainland Europe and the eastern Mediterranean also made it an entrepot city, in which overland trade goods were loaded and shipped to overseas ports. Most of Venice's oversea trade was focused on the Adriatic and countries on the eastern Mediterranean Sea; however, a few overseas trade routes were established in northern Europe via the western Mediterranean and the Atlantic Ocean. Venice's overseas trade relations in the western Mediterranean and northern Europe were not as strong as its western competitor, Genoa, but they were successful nonetheless.

During this time, two types of ships were being built by the Venetians to travel their many trade routes: round ships and galleys. The sail-powered round ships were used for large, inexpensive cargoes, and the galleys were used to transport more expensive commodities. Galleys were primarily powered by sail, but were operated by rowers when becalmed, to enter and exit ports, and when the vessels required more maneuverability. The large numbers of rowers, accompanied by trained guards, made the galleys more secure, but also made them more expensive to operate. Galleys were used to transport goods to a number of important cities in the Mediterranean, such as Alexandria and Aigues-Mortes, and Flanders, in the north of Europe. Their small autonomy determined that they had to stop at other port cities; this benefitted the galleys

since space was limited for provisions. Lisbon, for instance, was one such city that the Venetian galleys stopped at on the way to the North Sea. The galley of Flanders, named for its primary destination, traveled annually from Venice to the North Sea for a period of more than two centuries.

There is little published information about how many merchant galleys were traveling at any given period, but based on state records (from the Arsenal), in 1504 there were as many as 32 merchant or great galleys and 83 light galleys built or under construction.¹ Most of the information from this period is based on the limited records left by the state or, specifically, the Arsenal, where the vessels were built. While this information is generally reliable, it is sporadic either due to the secretaries at the time keeping not keeping constant notes, or documents being lost over time. In either case, when these records are researched, it usually results in a representative snapshot of one year or one transaction. The number of merchant galleys in 1504 does not take into account the number of galleys already built and how many of these vessels were warships. However, this statistic does indicate that a large amount of vessels were built in that city during just in one year. Despite the apparent abundance of vessels, no merchant galleys dating to this period have been discovered so far. The closest archaeological evidence consists of hull fragments of a war galley found in Lake Garda dating to 1509, and another galley found in Venice, at San Marco in Boccalama, dating to the early 14th century.² Hull remains of any type of vessel from this period are rare, and of those that exist fewer have

¹ Lane 1934, 242.

² For the Lake Garda galley see Scandurra 1972, 210, and Capulli 2003; for the Boccalama galley see Fozzati, 2003.

been published.³ Since galleys were relatively light vessels and carried small cargoes into open seas, the likelihood of finding an intact shipwrecked galley is relatively low. Instead, ship construction scholars have turned to textual and iconographic resources to learn about ships of the period. As noted above, state records are a good source of information on ships of Venice, but often describe the specifications a voyage or cargo or the Arsenal's inventory and do not describe how the vessel was constructed. The primary textual resources for shipbuilding are treatises: documents written about the principles of a subject, such as mathematics, shipbuilding, music, and astronomy. While treatise authors were often educated men able to write, their knowledge and experience of their subjects varied, thus lessening the treatises' credibility. With those limitations in mind, two known treatises dating to the early to mid-1400s discussing the galley of Flanders were researched for this study: the book of Michael of Rhodes, and the *Libro di Zorzi Trombetta da Modone* (the book of Giorgio "Trombetta" da Modone).⁴ From examining these documents, it is clear the book of Giorgio "Trombetta" da Modone contains significantly less dimensional information, and describes slightly different dimensions when compared to the book of Michael of Rhodes. A third treatise, *Fabrica di Galere* (Building of Galleys), is a copy of the Michael of Rhodes book, and is introduced in this thesis solely to illustrate the potential and limitations of using treatises.

In this thesis, some of the dimensions and measurements of the galley of Flanders, as described in Michael of Rhodes' book, will be used to generate a 3-dimensional (3-D)

³ Valenti 2009, 20; Harpster 2005, 356.

⁴ The *Libro di Zorzi Trombetta da Modon* is often referred to in English as the Trombetta Manuscript.

model of the vessel in the software program *Rhinoceros*® (Rhinoceros). With the limited data in the treatises, recreating the entire vessel would be an ambitious task that would likely create more questions than answers. It is important to remember that this model is an educated guess and was developed in order to identify the basic questions that are the foundations of any in-depth study. In this case, the primary question is: can the 3-D model yield information about hull capacity and displacement? For that reason, the model is simplified and focuses on just the portion of the vessel that can answer this question: the lower hull (construction) primarily the interior of the vessel.

I was hoping by looking at the hull capacity and displacement, I could examine the vessel's potential cargo capacity. However, little is published about how such a vessel was laden during this time, specifically what supplies and cargo were kept on deck versus in the hull. Even though the model generated in this case study provided information about capacity, little can be answered regarding the cargo distribution of the vessel.

By generating rough calculations of the vessel in the 3-D program, this case study showed that 3-D modeling programs and textual resources can be used to more closely examine vessel dimensions, capacity, and displacement. But this study demonstrates a sample of these resources' potential, which I hope will lead to more research about maneuverability, construction, and cargo distribution of the galley of Flanders.

CHAPTER II

VENICE: THE CREATION OF A TRADE EMPIRE

Geography

The location of Venice is an important factor in its rise to the head of a trade empire.

Venice is located on the eastern coast of present-day Italy. The land upon which the city is built is comprised of small islets, 117 in total, within a protected lagoon.⁵ This unusual natural design creates several waterways that dissect the city-state. Three kilometers to the west of the islands lies mainland Italy, and three kilometers to the east is the Adriatic Sea, which feeds into the Mediterranean (Sea). The Po and Piave Rivers feed the lagoon from the mainland. With a longitude of 45°26'N and latitude of 12°19'E, the city has a mild climate allowing for year-round use of the rivers and waterways. This abundance of waterways within, and around the islands, as well as their proximity to the Adriatic Sea, was a key factor in the city-state's naval and commercial success. In addition, Venice's advantageous location between mainland Europe and the eastern Mediterranean led to its success as a major trading hub, by acting as a crossroad between land and overseas trade.⁶

History: From the Beginning to the Decline of the Trade Empire

Not unlike other older cities, the lack of historical records to trace back to the earliest settlement makes it difficult to know when people first inhabited the city of Venice. It is

⁵ Crouzet-Pavan 2002, 10. The city began as plots of dry land, and as the city expanded the islets were drained and added to the city's usable land.

⁶ Plumb 1961, 5.

thought that Romans from nearby northern cities of Italy were the first to occupy the islands. Evidence suggests that many Romans settled in this difficult terrain while fleeing the waves of invaders, first the Goths from Western Europe, and in the 5th century C.E., the Huns from Eastern Europe and Asia.⁷ Since these invaders destroyed towns on their way to Rome, it was safer, though less desirable, for the local people to move closer to the lagoon, and in some cases to the islands in the lagoon.⁸ First written accounts of inhabitants in the area date to the 6th century when the Lombard people invaded, forcing the locals to flee and settle in the Venetian Lagoon.⁹ This early settlement flourished because of the natural resources, mainly the water. They created an economy from the fish in the lagoon and found ways to procure and sell the natural salt from the sea.¹⁰ As they pursued making a living on the islands, the water continued to provide a natural security against enemies.¹¹

Unlike other areas during this time, the inhabitants of the lagoon were self-governed.¹² Probably starting as early as the city's establishment, the urban structure of Venice consisted of a group of individual parishes divided by canals; there were 60 parishes by 1200 C.E..¹³ This division and parish-based system of government resulted in each parish having separate customs, markets, and identities; they were also unique in their trade as each manufactured different commodities. For example, the west end of the

⁷ Martin 2001, 9; Norwich 1982, 4.

⁸ Lauritzen 1978, 18.

⁹ Martin and Romano 2000, 39; Martin 2001, 9.

¹⁰ Martin 2001, 9.

¹¹ Supra n. 9.

¹² Martin 1992, 8; Thurbon 1980, 10.

¹³ Lane 1973, 12.

Grand Canal was known to house most of the cloth industry, while the eastern part of the city housed sailors and workers in the shipyards.¹⁴ Since streams and channels of water divided the city, access between parishes was limited to footpaths, wooden bridges, and ferries via the waterways.¹⁵

In 697 C.E., the parishes united more formally and elected a duke to rule, who was later referred to as the *doge*.¹⁶ Each parish was represented by an individual *doge*, who reported to the city's *doge*.¹⁷ In time, the city-state government grew and incorporated legislative bodies. A main governing body of Venice was the Great Council. The Great Council was comprised of (a group of) the city's prominent men; it was their job to keep the *doge*'s power in check. In addition to the Great Council was the Senate, whose members were elected from the Great Council. The Senate was a key component to the livelihood of Venice due to its authority over everything relating to matters of war and commerce, both of which occurred primarily at sea.¹⁸

As the major empirical power in the Mediterranean shifted from Rome to Byzantium, so did the allegiance of Venice. Venice's relationship with the Byzantines began as early as the late 7th century and the establishment of Venice's first *doge*.¹⁹ In the beginning the *doge* took orders from the Byzantine emperor, and in return the city was protected by the

¹⁴ Lane 1973, 12, 14.

¹⁵ Lane 1973, 12.

¹⁶ Thurbon 1980, 11; Lauritzen 1978, 22.

¹⁷ Lane 1973, 5.

¹⁸ Thurbon 1980, 11.

¹⁹ Lane 1973, 5.

Byzantines.²⁰ Additionally, Venice provided a place to export Byzantine goods and was a source of supplies.²¹ The city's safety, together with the Byzantine Empire's financial and political support, allowed Venice's foreign relationships to grow.²² For this reason, the Venetians' loyalty laid more with the faraway empire of the Byzantines than with other Italian city-states, such as Milan or Florence.²³ This loyalty shifted slowly because during the First and Second Crusades, Byzantium was considered an ally and Venice even provided the Empire with ships. Over time, Venice's government was better established and stronger, and thus Venice needed less assistance from the Byzantine Empire.²⁴ Their amicable relationship clearly changed in 1171, when the Byzantine capital of Constantinople rioted against Western Europe, specifically Venice, and anti-Venetian sentiment subsequently rippled through the rest of the Byzantine Empire.²⁵ This caused further tension, which ultimately climaxed with Venice playing a major role in the capture of Constantinople in 1204 during the Fourth Crusade.²⁶ Venice was rewarded with control over other cities within the former Byzantine Empire, including three-quarters of Constantinople, the island of Crete, and Negroponte.

During the early Crusades, Venice continued to grow, expanding in population from 80,000 in 1200 C.E. to 160,000 by 1300 C.E. Unfortunately, the Black Death depleted

²⁰ Lane 1973, 5.

²¹ *Supra* n. 20.

²² Plumb 1961, 95.

²³ Plumb 1961, 102.

²⁴ Since Venice was an autonomous entity and was not governed by a larger country or city, it is considered to be a city-state and not just a city.

²⁵ Thurbon 1980, 19.

²⁶ Thurbon 1980, 36.

Europe's population in the mid-1300s.²⁷ The Black Death hit Venice in 1348 and cut the population by sixty percent in the first 18 months. The population eventually recovered and was stable by the 16th century, with approximately 170,000 inhabitants.²⁸

With a stable population, Venice was able to increase trade and utilize the ports and islands it governed throughout the Mediterranean, Adriatic, and Aegean Seas.²⁹ Each port varied in size and complexity, but all were located along Venetian trade routes. Figure 1 shows a sample of some trade routes during the 13th century. Some ports and islands provided docking and supplies, while others were colonies inhabited by Venetians, such as those on Crete and Corfu.³⁰ In addition, Venice had set up strong trade relationships with cities which they did not control, such as Tyre, Acre, and Alexandria, to name a few.³¹ The economic and political control that Venice had over these colonies and port cities was invaluable during the height of Venice's trade empire, which peaked in the 15th century.³² Venice continued to grow in population and success; some authors place the population of the city in the 16th century at 170,000, with 2 million in subject territories.³³ Venice, along with Genoa and Pisa, ranked among the foremost maritime republics in Italy during Middle Ages.

²⁷ Lane 1973, 18.

²⁸ Martin and Romano 2000, 1.

²⁹ Plumb 1961, 97.

³⁰ Morris 1980, 7.

³¹ Plumb 1961, 97.

³² Thurbon 1980, 45.

³³ Martin and Romano 2000, 1.



Fig. 1. Trade routes in the 13th century with the Venetian cities underlined (modified from Map 4, Lane 1973, 39.)

Venice was able to maintain its trade dominance until the first half of the 16th century. While several issues contributed to the decline, Venice's competitors may have been the biggest factor. While Genoa had a long history of competition with Venice, by the 16th century, competition had extended further than the Genoese, and included the Portuguese and the Spanish. Between 1480 and 1530, the Portuguese and Spanish were looking for new routes to the east using waterways other than the Mediterranean Sea. Portuguese success sailing around the southern cape of Africa relinquished some trade within the Mediterranean to the Venetians. Unfortunately, once the new spice routes to the east via Africa became established, the demand for the Venetians to import spices from the Levant decreased. Scholar Frederic Lane found in the diary of Girolamo Priuli,

published in *Rerum Italicarum Scriptores*, that during the early 16th century, the Venetians were importing 1 million pounds of spices per year, versus the average of 3.5 million pounds in previous years.³⁴ Despite this competition, the Venetian great galleys continued to carry spices until 1570, though by the beginning of the 16th century no new vessels were being added to the fleet.³⁵

Trade Logistics: An Overview

In addition to well-located ports and a relatively large population many factors contributed to the growth and success of the city-state. Unlike other cities in Europe during the Middle Ages, Venice consisted mostly of swamps and islands, thus eliminating the possibility of vast individual land ownership and feudal systems of government.³⁶ For this reason, the Venetians, like the lagoon's first inhabitants, continued to profit from their natural topography. From the beginning, it was necessary to build vessels to move people and goods, because it was more efficient to travel the waterways than the maze of walkways and bridges. Venetians maintained canals and waterways for more effective shipping and expanded trade goods beyond fish and salt.

The layout of the city meant that ships weighing as much as 200-tons could maneuver along canals leading to the Rialto area at the heart of the city.³⁷ Additionally, most of the city's waterways had docks and wharves, even the private homes of merchants, allowing

³⁴ Lane 1966, 12-13.

³⁵ Lane 1966, 11, 14.

³⁶ Thurbon 1980, 11.

³⁷ Lane 1973, 14.

for movement of both goods and people directly to warehouses and markets.³⁸ Since land-based transport required navigating narrow, winding streets and crossing numerous bridges, this easy access to the warehouses and markets made the task of delivering goods more efficient and therefore, cheaper. In most port cities, commercial goods were unloaded from the ship to stevedores, who would transport the goods by cart or wagon to the warehouse. Transportation of goods by cart increased exponentially the cost because of the time and labor required.

Venetians did well exporting local goods including glass, woolen products, silks, salt, and chemicals, but excelled in the transportation and redistribution of imported foreign commodities.³⁹ The city brought in metals, such as raw silver, copper and steel from Germany and Bohemia; Constantinople and Greece supplied silks; Crete produced wine; and cotton, sugar, salt, and wine were brought from Cyprus.⁴⁰ Additionally, the Near East had luxury goods to trade with Venice, such as cotton, sugar, spices, gold, silver, glass, silks, damasks, jewels, and indigo.⁴¹ Alexandria provided silks, silver dishes, and papyrus.⁴² Some of these goods came from India, Arabia, and China, and were transported over land by camel caravans, and then across the Red Sea, to the city of Alexandria.⁴³

³⁸ Morris 1980, 17.

³⁹ Plumb 1961, 5; Thurbon 1980, 45.

⁴⁰ Thurbon 1980, 45; Plumb 1961, 101.

⁴¹ Thurbon 1980, 45; Plumb 1961, 100.

⁴² Plumb 1961, 5.

⁴³ Thurbon 1980, 45.

Slaves were an important part of Venice's trade, beginning as early as the 9th century, when they were sold to Europe and the East. In the 14th century, most slaves were Georgians, Circassians, and Russians; they were brought to Venice or Cyprus to work, or sent to North Africa to be sold, often through the well-established slave market of Alexandria.⁴⁴ Eventually, Venetians also transported free peoples. During and after the Crusades, many pilgrims and crusaders traveled to the Holy Land on Venetian vessels.⁴⁵

One change that the Venetian merchants made in the 14th century was the use of foreign commercial agents in the destination city.⁴⁶ Until this time, Venetian merchants traveled with their goods to the import city to sell their wares. If the merchant did not travel with the wares, he sent a trusted (traveling) merchant.⁴⁷ The merchants then switched to using local agents in foreign countries that facilitated the arrival and sale of the imports from Venice.⁴⁸ One problem with this system was deciding whom to trust in a foreign city. The solution was family partnerships, in which one family member was in Venice and others lived in foreign ports. This provided a trusted merchant at the import city and made the entire family responsible for the profits and loss.⁴⁹ Partnerships that were not based on kin were also common during this period, though these were usually contracted for a finite period of time.

⁴⁴Thurbon 1980, 46-7; Plumb 1961:5; McNeill 1974, 54. One calculation indicated that approximately 2,000 people were shipped from the Venetian-ruled city of Caffa (in present day Greece) to Egypt each year.

⁴⁵ Plumb 1961, 101.

⁴⁶ Thurbon 1980, 48.

⁴⁷ Supra n. 46.

⁴⁸ Supra n. 46.

⁴⁹ Lane 1973, 138.

While merchants were in charge of the trade relations, the Senate controlled part of the long sea trade. The Senate's decisions determined the size of the fleet, what was shipped, and essentially, the supply and the demand of the city's market.⁵⁰ Even though they dictated the market, they also fuelled the industry, by committing public funds to the merchants, the merchant galley fleet, and the Arsenal.⁵¹ They subsidized voyages, especially those to the North Sea, though as the city's merchants became successful subsidies lessened.⁵² Consequently, some of the members of Senate were also merchants and would sometimes vote in favor of their own commercial interests.⁵³

The government took into account foreign relationships and the economy when making decisions; one example was the increase in ships traveling to northern Europe via the Atlantic. Traditionally, wares going to and from places like Bruges, in Flanders, traveled overland via Germany.⁵⁴ Germany had a good relationship with Venice, but the overland route was not always used due to the substantial cost. This method of transport also relied heavily on mutual goodwill between the political entities, something not to be taken for granted, considering the ever-changing relationships between countries.⁵⁵ To avoid problems caused by the Germans, and later the French, Venice relied more heavily on a water route to areas like Flanders.⁵⁶

⁵⁰ Lane 1944, 51.

⁵¹ Thurbon 1980, 48.

⁵² Lane 1966, 195, 210. The subsidies of voyages to the north began in 1314.

⁵³ Lane 1944, 49.

⁵⁴ Lane 1944, 55.

⁵⁵ Supra n. 54.

⁵⁶ Lane 1973, 126.

As seen with Germany, it is important to remember that many foreign relationships and events affected Venetian trade. Wars, hostile entities, and civil unrest impacted trade and trade routes, especially when these conflicts favored a competitor's trade interest. However, foreign events also facilitated new trade opportunities, as in the acquisition of cities following the Crusades.

Impediments to Venice's commercial interests often did not occur as a result of events within the city-state or at a foreign port, but on the sea itself. Pirates were a constant threat to merchant ships within the Mediterranean.⁵⁷ For this reason, merchant ships, especially galleys carrying precious cargo, were often escorted by armed vessels, and fleets of armed galleys were regularly deployed as guard fleets to patrol the trade routes.

Merchant Ships and Their Established Trade Routes

In order to better understand the armed escorts and the security of the merchant ships, the roles of shipbuilders, owners, and merchants must be discussed. In Venice there were four main vessel types produced in the city: military vessels, barges, gondolas, and merchantmen. While most cities with military fleets contracted government shipwrights, Venice did not build its own military ships until the beginning of the 14th century.⁵⁸ Private shipwrights built the ships, and the state housed the military vessels in the Arsenal.⁵⁹ Originally, the Arsenal was used only for warehousing equipment, but eventually it became a shelter for the ships, and subsequently became the sole

⁵⁷ Plumb 1961, 5.

⁵⁸ Bondioli, 2003, 11.

⁵⁹ Supra n. 58

manufacturer of military ships.⁶⁰ According to Mauro Bondioli, many factors contributed to the change of the Arsenal into a construction area. The main reason is that accomplished shipbuilders became employed at the Arsenal by the state to ensure that they would not leave the city or the country.⁶¹ Essentially, the state did not want to lose talented builders (or commerce) to private or foreign competition.

The state and private shipbuilders were building vessels for commerce as well as military ships.⁶² All galleys built either privately or by the state were regulated by the government during construction to ensure that if the ship was commissioned for war use, it could easily be outfitted and maneuvered by the military.⁶³ By the 15th century, all great galleys were built at the Arsenal, while round ships of commerce were built by private entrepreneurs in private shipyards.⁶⁴ One of the reasons for this was due to the nature of the cargo; great galleys were used to transport luxury goods. These convoys of valuable cargo were overseen by the state and heavily guarded.⁶⁵ At the end of the 15th century, with a shift in vessel preference from galleys to round ships and the need for more round ships, the government went to private shipbuilders for its vessels.⁶⁶

⁶⁰ Supra n. 58. Galleys had to be removed from the water in order to preserve their hull from wood-boring creatures.

⁶¹ Bondioli 2003, 11.

⁶² Lane 1973, 48.

⁶³ Lane 1973, 48; Martin 2001, 10.

⁶⁴ Lane 1966, 8.

⁶⁵ Thurbon 1980, 52.

⁶⁶ Lane 1966, 8.

During the 14th and 15th centuries, commercial vessels leaving Venice were either state regulated or free voyages, which were owned and operated by one or more private merchants. Some aspects of the free voyages were regulated by the *Doge*, but owners did not have to register the route, time, freight rates, and vessel type.⁶⁷ Such voyages were subject to laws that regulated the types of cargo transported, the sailing routes, and the composition of the fleets. These fleets were loaded during special times of the year and were called *muda* (plural *mude*).⁶⁸ There were normally *mude* leaving Venice each year in the fall and spring, and these voyages were heavily guarded by the state.⁶⁹ These trips were made by both round ships and galleys, albeit the round ships often carried bulk cargo and the galleys carried the more expensive goods. Luxury cargoes were always transported on regulated voyages.⁷⁰ Eventually, the regulated voyages became more strictly controlled with the introduction of licenses. Merchants would apply for the license and, if approved, an admiral would be appointed to the fleet to guarantee that the ships traveled on time and were well guarded.⁷¹ The fleets traveling to Flanders at the beginning of the 14th century were probably the first historically licensed voyages.⁷²

At the beginning of the 14th century, the fleets traveled to various ports throughout the Adriatic Sea, the Black Sea, throughout the Mediterranean Sea, and into the Atlantic

⁶⁷ Lane 1966, 195.

⁶⁸ McNeill 1974, 60. The *muda*, or regulated voyages, were common by 1330 and continued until approximately the 1530s.

⁶⁹ Lane 1966, 195.

⁷⁰ Supra n. 69.

⁷¹ Supra n. 69.

⁷² Lane 1966, 208-9.

Ocean.⁷³ Toward the 15th century the great galleys were divided and committed to seven specific routes, named for their primary destinations: Alexandria, Aigues-Mortes, Flanders, Barbary, Romania (previously named the Black Sea route), Beirut, and northeast Africa. All of the vessels traveled once per year, except the galley of Alexandria, which occasionally made the voyage twice yearly in response to changes in supply and demand of exotic goods, such as silks and spices.⁷⁴

Throughout Venice's history of shipbuilding, both public and private, the number of ships built and sailed varied for numerous reasons. In order to understand these fluctuations in numbers of built ships, both the ship types and their purposes must be examined. During the 14th century merchant ships were divided into two main types, according to hull shape and means of propulsion: round ships and galleys.⁷⁵ Round ships, propelled exclusively by sails and with hulls bearing length to beam ratios around 3:1, were used mostly for bulk trade and generally less luxurious goods, and sailed shorter trade routes, mainly throughout the Adriatic. During their peak from 1420-1450, these vessels made up the majority of the merchant fleet, which may have numbered as many as 300 ships.⁷⁶ Until the 16th century, the round ships were considered "unarmed" ships; they did not travel in convoys and carried fewer armed men (and unarmed, for that

⁷³ Lane 1966, 200

⁷⁴ Thurbon 1980, 52-53.

⁷⁵ Lane 1944, 50. In other countries, cogs were in use in the 15th century, but they were risky and unreliable. In addition, the Senate forbade merchants to use cogs and insisted they use the great galleys instead.

⁷⁶ Lane 1966, 5.

matter) than the galleys.⁷⁷ Not all round ships were exclusively engaged in short sea trade, however; some round ships traveled to distant ports, for goods such as cotton, alum, grain, and oil, less valuable items in comparison to the goods carried by the galleys, and thus standing a reduced risk of being targeted by pirates.⁷⁸

In contrast, galleys had hulls with length to beam ratios between 5:1 and 7:1, and were propelled mainly by sails, although they could be rowed to enter and exit harbors, when they were becalmed, or when they faced emergencies. These ships carried primarily luxury goods and traveled long distances. Great galleys could carry between 140-200 tons below deck, plus have room for over 200 men, of whom at least 20 were archers employed to protect the vessel.⁷⁹ There were around 170 oarsmen who were also expected to defend the vessel if attacked. In comparison to the Mediterranean round ships and the cogs from northern Europe, merchant galleys were more maneuverable and safer.⁸⁰ With rowers, the swift galleys could avoid attacks from pirates or enemies, maneuver around rocks and shallows, and move into and out of harbors easily. Additionally, the galleys often traveled in convoys within the *muda*. Merchant galleys were required to travel in a convoy, while round ships did not usually travel together. While the convoy did split up along the way to travel to different ports, it was desirable to have a minimum of two galleys together at all times. On the return trip, one vessel was often waiting at a port to reconvene with the entire convoy so they could travel back

⁷⁷ Lane 1966, 16; 206; Lane 1944, 9. In the 16th century, round ships began to carry cannons for protection.

⁷⁸ Lane 1966, 6.

⁷⁹ Lane 1966, 5; Lane 1934, 24.

⁸⁰ McNeill 1974, 60.

as a group; this was an inconvenience, especially financially.⁸¹ Between the more crew members to pay, the license of a regulated voyage, and time spent waiting in ports after trade was completed, and longer voyages overall, merchant galleys were more expensive to operate than were round ships.⁸²

Due to shifts in cargo demand, the number in the fleet fluctuated as seen with the fleet sizes of both galleys and round ships. For example, alum was brought from Asia Minor until 1460, when it was obtained from newly found mines in Europe. This, in conjunction with other factors, including the exorbitant taxes imposed by the Ottoman sultan resulted in less ships traveling east.⁸³ Other commodities, such as wine, sugar and silk, also caused changes in trade patterns and fleet sizes when new sources of production were established. Even though the number of vessels traveling to specific ports changed occasionally, the overall number of round ships and galleys traveling from Venice remained relatively stable. The two major periods when the number of ships fluctuated were during the second half of the 15th century and the first half of the 16th century. In this hundred-year span, both galleys and round ships experienced a height of production, although their heights were at different times. Galleys were more numerous in the second half of the 15th century and the number of round ships was reduced by half.⁸⁴ This was due to the large amount of luxury goods imported, especially spices. With the new century, round ships increased in number and galleys decreased. This shift

⁸¹ Lane 1966, 206.

⁸² Lane 1966, 5, 7; Mc Neill 1974, 61.

⁸³ McNeill 1974, 56.

⁸⁴ Lane 1966, 8.

is in part due to the discovery of new routes to the East, resulting in a lesser reliance on Venice and its established spice route to the Levant. In addition, round ships were beginning to be outfitted with cannon(s) and better rigging.⁸⁵ In these conditions, galleys were no longer far safer than round ships, and their armed convoys were twice as expensive to employ.

Decline in Trade

As discussed earlier in this chapter, Venice's commercial success was related to the Venetian merchants' ability to build and maintain trade vessels through the Arsenal; therefore, the decrease in ships being built had a negative impact on the trade business. Due to the increase in competition, especially in the spice trade, Venice did not need as many ships built. In addition, timber shortages impacted the number of vessels Venetian shipwrights were able to produce. Both the Arsenal and private shipbuilders used the forests on the nearby mainland as their primary wood source, and timber depletion became an issue in the second half of the 15th century.⁸⁶ From the beginning, the Arsenal had legal authority over how timber was distributed and closely monitored its use. By 1559, feeling that the Arsenal's supply was threatened; the Senate mandated that private shipbuilders funded to build state vessels should acquire their timber from sources outside of Venice.⁸⁷ This directive had little impact on the timber depletion, because private shipbuilders had been obtaining most of their timber outside of Venice since 1546 (as much as two thirds of their timber), when a timber license tax was

⁸⁵ Lane 1966, 14.

⁸⁶ Lane 1966, 8.

⁸⁷ Lane 1934, 231.

implemented.⁸⁸ As a result, in the late 1500s Venice began to buy foreign-built ships; this shift highlights the apparent decline in Venice's shipbuilding history and trade success and the rise of trade in other countries, such as Portugal and Spain.⁸⁹

Venice's relationship with the sea began when the first inhabitants took up shipbuilding and trading of natural resources. This created a foundation for the city's success in foreign trade and sea travel. The importance of maritime trade penetrated all aspects of the city, from the layout of the city to the roles and responsibilities of the governmental bodies. Venice's foreign relations and prime location led to success in trade.

Consequently, the decline of Venice's trade empire was a result of other countries utilizing the resources of the sea that provided the Venetian's wealth and success. As Venetian success declined, other maritime cities were gaining strength and replacing the waning empire with new trade routes and ports.

⁸⁸ Lane 1966, 19.

⁸⁹ Lane 1966, 20.

CHAPTER III

THE GALLEY OF FLANDERS AND THE EVIDENCE OF TREATISES

By the 15th century Venice transported and traded goods to many ports using round ships and merchant galleys. The merchant galleys traveled primarily to seven established destinations: Alexandria, Aigues-Mortes, Flanders, Barbary, Romania, Beirut, and northeast Africa. Each route had a convoy of merchant galleys that traveled once a year, a *muda*, with the exception of Alexandria's convoy, which occasionally traveled twice in a year.⁹⁰ Merchant galleys were required to travel in a convoy, while round ships did not usually travel together.

The convoy to Flanders completed one voyage each calendar year leaving in July, and traveled one of the longest of the seven routes.⁹¹ In addition, it was the only route to venture into the Atlantic Ocean, and in order to overcome this obstacle, the galleys had to be well designed and built. Unfortunately, at present, no hulls of the galley of Flanders exist in the archaeological record, so textual resources must be used exclusively to study this galley. The three known documents, or treatises, existing today that discuss the galley of Flanders's design are (a) the book of Michael of Rhodes, (b) the book of Giorgio "Trombetta" da Modone, and (c) a mid-15th century partial copy of Michael of Rhodes' book known as *Fabrica di Galere*, after its publication in 1840 by French

⁹⁰ Lane 1966, 206.

⁹¹ Thurbon 1980, 53.

historian Auguste Jal.⁹² This thesis will focus on the first two treatises, but it is important to know of the existence of the *Fabrica di Galere*. These manuscripts were written by authors who were not shipwrights of the state, although it is possible that the descriptions of the ships contained in them may have been copied from an original owned by the state.

This chapter will include an overview of the route's logistics, followed by a description of each treatise's contents, with emphasis on the information regarding the galley of Flanders. As will be discussed later in this chapter, the *Fabrica di Galere* is a copy of the book of Michael of Rhodes and the *Fabrica di Galere* is introduced in this chapter for the purpose of showing potential and limitations in using treatises.⁹³ The galley of Flanders's descriptions from the Michael of Rhodes book and the Trombetta da Modone book will be compared with each other for a better understanding of the dimensions and design of the galley. The most reliable dimension information from this comparison is used in the 3-D modeling of the ship's hull and will be discussed in the next chapter.

Logistics of the Route

The annual Flanders *muda*, or regulated voyage, was a dangerous undertaking because it ventured into the Atlantic Ocean, but the traded commodities and the commercial relationships with the cities in the North Sea were crucial to the Venetian economy.

⁹² Jal 1840.

⁹³ Rossi 2009a, xvi-xvii.

While the route was named for traveling and trading with the region of Flanders, the convoy conducted as much trade in English ports as it did with Flanders on this voyage.⁹⁴ Traditionally, the fleet split upon reaching the English Channel, with one half traveling on to Flanders port of Sluys and the remainder going to London, Sandwich, or Southampton.⁹⁵ In London, the ships picked up tin, lead, amber, and wool and in Flanders the commodities obtained were hemp, thread, fustian (a heavy cotton fabric), and linen.⁹⁶ Items such as wine, spices, silks, alum, and goods from the east were exchanged at these northern cities by the Venetian merchants.⁹⁷

To further supplement profits, additional trading occurred during the voyage. Galleys needed to take coastal routes because of their lack of freeboard, which made them more susceptible to being swamped in the open ocean.⁹⁸ The lack of freeboard reduced the amount of room on board for provisions, requiring frequent stops at coastal ports. However, this benefited the crew and merchants, as they could conduct minor trading at ports such as Palermo, Mallorca, Málaga, Lisbon, and Cádiz.⁹⁹ Unlike the primary cargo, which were established transactions going to and from Venice; this secondary trading by

⁹⁴ Lane 1966, 4.

⁹⁵ Williamson (1972, 49) notes that the England-bound portion of the fleet would have to wait for the Flanders ships to return before the entire convoy could return to Venice. See also Hazlit 1900, 569; Lane 1966, 4; Stahl 2009b, 54.

⁹⁶ Long 2009, 13; see also Williamson 1972, 49, 129; Thurbon 1980, 53. In addition, McNeill (1974, 52) notes that in some cases, the English wool was taken to Flanders to be converted into fine cloth; this process was also done in Italy. Then the Venetians would sell the finished cloth to the Levant or in Europe.

⁹⁷ Williamson 1972, 49; McNeill 1974, 55.

⁹⁸ Pryor (1988, 56) notes even when the merchants were capable of sailing the direct route through open ocean, they preferred to use cargo space for merchandise rather than provisions making stops for provisions and in turn, trade, a necessity.

⁹⁹ Thurbon 1980, 53; Lane 1966, 7.

the crew consisted of various sellable wares that were small enough to be kept in the limited space available for their personal gear.¹⁰⁰

The earliest organized fleet of galleys traveling to the North Sea from Venice sailed in 1315.¹⁰¹ Ships most likely made the trip to Flanders and the North Sea for trading prior to this date, but they were not formally organized, resulting in a lack of documentation of these voyages. The Flanders *muda* usually averaged a total of 12 months to travel north, trade, and return to Venice.¹⁰² The ships left in July and would return in the spring or summer of the following year; although there is documentation showing that the Flanders convoy would occasionally depart as early as March or April.¹⁰³ The annual route was sailed by the Venetian merchant galleys for over two centuries, with the last documented voyage occurring in 1532.¹⁰⁴

Since the establishment of the route, the vessels traveling to Flanders were constructed and owned by the state. All ships were built in the Venetian Arsenal.¹⁰⁵ The Senate

¹⁰⁰ Lane 1966, 7.

¹⁰¹ According to Lane (1966, 209) the Flanders route was one of the last of the major seven merchant galley routes to be established. McNeill (1974, 48) notes that the Straits of Gibraltar were opened in 1291 after a Genoese buccaneer gained control of the Straits by stopping the Moroccan fleet which controlled all passage through it. Subsequent travel from the Mediterranean, especially Italy, to the North Sea was easier, and became a common practice for Genoese and Venetian merchant fleets in the beginning of the 1300s.

¹⁰² Williamson (1972, 49) remarks that in some cases, the voyage took longer due to weather, hostile waters, loading delays, or political unrest.

¹⁰³ Lane 1966, 110; Stahl 2009b, 55; Thurbon 1980, 53.

¹⁰⁴ Williamson 1972, 49.

¹⁰⁵ The primary reason the galleys were built and owned by the state was to ensure they would be the right size and maneuverability to be used as a warship. The galleys were first and foremost intended for war and used as merchant ships in times of peace, according to Lane (1966, 225). The Arsenal was founded in 1104 and was initially a place to house naval stores and weapons, but eventually became the primary ship building location for the state (Lane 1934, 129).

established the number of ships to go on each voyage, based on Venice's political and economic status, and then auctioned off the use of the ships to the highest bidder, usually a nobleman or private company.¹⁰⁶ The winning bidder, known as the *patron*, or galley master, would fill his galley with wares from his own company and other merchants. Freight rates were fixed by the Senate, not the *patron*, and were based on the commodity, thus allowing any business or individual with the requisite capital to be able to send wares, not just the biggest and richest businesses.¹⁰⁷ Despite government fees and restrictions, merchants still found the situation profitable because safety was at a higher standard on the voyage and because they maintained some control over quality and prices of their merchandise. The voyage's complete safety could not be guaranteed; however, the high value of the commodities dictated that the galleys were more heavily protected than round ships. This was in part due to the design of the vessel, since the large number of oarsmen needed to maneuver the vessel meant there was an equal amount of men to defend the ship, and the arms carried on board were supplied by the Arsenal.¹⁰⁸

The prosperity of the galley routes was not always guaranteed. In the early years the government offered subsidies or free use of galleys as incentives to develop the Flanders route, but by 1319 it was successful enough that such incentives were no longer

¹⁰⁶ McNeill 1974, 62; Lane 1966, 45. See Lane (1966) for a more elaborate explanation of joint ventures, private investors, and state regulations of galleys.

¹⁰⁷ McNeill 1974, 62-63.

¹⁰⁸ Lane 1967, 12; Lane 1934, 24.

necessary.¹⁰⁹ Moreover the state did not set a maximum or minimum number of galleys that could travel with the fleet, thus allowing for the natural commercial fluxes to dictate the fleet size.¹¹⁰ The number of galleys going to Flanders ranged from four to nine per year.¹¹¹

Since the galleys of the Flanders fleet were built at the Arsenal, the dimensions were regulated by the state. The vessels' dimensions and tonnage changed over time, showing a growing trend in the capacity to carry larger cargoes. At the beginning of the 1400s the great galley had a capacity of around 140 tons, maximum. By 1481, the galley's size increased so much that the Senate put a restriction of 210 deadweight tons maximum on the great galleys. Ultimately the Senate noticed that due to the enlarged size, the galleys were unable to be maneuvered by oars, which lead to the Senate lowering the tonnage limit in 1520 and again in 1549.¹¹² Tonnage and length were often state-mandated regulations and some state records describe the standards and regulations put forth by the Senate. The physical dimensions and proportions of the ship are more difficult to determine as they were not included in the state records and often the shipwrights did not write them down in formal documents. Shipbuilding was a craft in which the

¹⁰⁹ Lane, 1966, 211.

¹¹⁰ Lane 1966, 209; Hazlit (1900, 568) comments that political situations also dictated the size of the fleet; in times of peace higher than average number of ships were deployed and fewer than average during wartime.

¹¹¹ According to Lane's (1966, 213) research, looking at the surviving registers in *Le Deliberazioni del Consiglio dei Rogati (Senato) serie Mixtorum*, between 1328 and 1334 the fleet size ranges from 4 to 9 ships. Stahl (2009b, 55) notes the fleet size in the mid-fourteenth century could get as high as 8 or 9, but the fleet traveling to Flanders between 1395 and 1435 was four or five galleys. Kedar (1976,17) noted the convoy had 4-9 galleys in the years between 1328-1334, but it was down to 3-5 in 1390 because between 1335 and 1410 the average tonnage of the merchant galley increased from 150 to 200 tons. The larger cargo capacity meant fewer galleys were needed in the convoy.

¹¹² McNeill 1974, 258.

proportions, ratios, formulas, and rules were settled through experience and passed down orally from father to son.¹¹³ It is possible that rules for the construction of different types of ships were written down at the Arsenal, but none has been found so far. To shed some light on the size and shape of these ships, the Michael of Rhodes book and the book of Trombetta da Modone, generally referred to as treatises, will be examined in the following sections.

Utilizing Treatises on Shipbuilding

Presently, treatises are one of the best resources for obtaining information on ship dimensions.¹¹⁴ The books of Michael of Rhodes and Giorgio “Trombetta” documents contain personal information. Their subjects include such topics as philosophy, music, art, architecture, medicine, astronomy, and economics. The length, expertise, and details of the matters treated depended on the author’s own interests and knowledge.

Both treatises considered in this study discuss ships in a complementary way, and thus vary in terms of what and how much of the construction process is discussed; often the documents contain the proportions or ratios of a vessel. Some include instructions on how each component was designed and produced, the order in which components were assembled, and how the ship was fitted together. In some cases, the origin of the timber and how it was procured is discussed, as well as sail and rigging information. To supplement the text, illustrations of the vessels’ components or the finished ship were

¹¹³ Lane 1934, 54.

¹¹⁴ At the time of writing, there exist no known remains of Venetian galleys that traveled to Flanders.

sometimes included; in both cases drawn by the authors in spite of their limited expertise as illustrators.

At first glance, some texts on shipbuilding appear to contain all the information needed for the construction of a vessel, but in attempting to reconstruct an actual hull, their shortcomings become widely apparent. Both books are difficult to use for modern reconstructions of historic vessels, primarily because the documents may not be credible or even complete. The credibility of the treatise is dependent on many factors and it is important to research the author and the treatise prior to using it as a resource. To better understand the limitations of the treatises in this chapter, some of the potential issues of the documents are discussed here.

One reason errors occur in the text is due to the author's level of expertise. The author of a treatise was not necessarily an expert or even had hands-on experience with their topic. Authors who did not understand the topic were prone to writing down incorrect measurements or presumed construction procedures. In most cases of known shipbuilding treatises, the text was not written by shipwrights, but by educated men who worked on or were interested in ships, as we will see with the forthcoming examples. Furthermore, if the treatise's author is unknown or anonymous, the credibility of the document can be difficult to assess.

In some cases, the credibility is compromised because the treatise is not the original text, but a copy, in which numbers may have been transposed, information omitted, or words or phrases incorrectly transcribed. Human error is a factor with each copy made, resulting in a final document that can be far from the original text and measurements of the vessel. In addition, whoever copied the document may not have had the same level of expertise as the original author. Often the original document does not survive and so the errors are not easily identified.

The usefulness of a given treatise could also be compromised by the audience for whom the document was written. For example, if the author intended the document for an audience knowledgeable in shipbuilding, then basic shipbuilding technique was assumed, and was thus omitted. It also should be noted that most shipwrights of the period did not learn how to build a ship from texts, but from proportions, geometric rules of thumb, and practical methods passed down orally. Over time these basic techniques have been lost with the craft, complicating the use of the treatises by modern scholars. While it appears that treatises are not a reliable source of data, with supplementary research and caution, most of these documents can provide a wealth of information about shipbuilding.

Treatises on the Galley of Flanders

For the purposes of this analysis, two texts dating to the Late Middle Ages, specifically from the first half of the 15th century, discussing the galley of Flanders will be reviewed:

the book of Michael of Rhodes, and the book of Giorgio “Trombetta” da Modone.¹¹⁵ I will briefly be mentioning a third treatise, the *Fabrica di Galere*, which is a copy of the Michael of Rhodes book. This third treatise will be discussed briefly prior to the Michael of Rhodes book because it will supplement the text from the Michael of Rhodes book as well as introduce potential relationships between historic documents, such as copying. A description of each manuscript and its specifications for the galley of Flanders’s will be presented in the following section and examined with measurements written in the Venetian units of paces, feet, palms, and fingers. The units of measurements used were generally ergonomic, such as the lengths of body parts or strides, but they had relative values associated with them, so as not to create variances between builders. There are 16 fingers in 1 Venetian foot, and 5 Venetian feet are equal to 7 palms, or 1 pace. One Venetian foot is equivalent of 1.142 modern English feet or 0.348 meters. Historian Ulrich Alertz (1995, 155) cautions that these values changed over time and that the aforementioned conversion is based on the surviving texts and should not be assumed when applying to other vessels and treatises.

¹¹⁵ The Late Middle Ages, from the first half of the 15th century, were chosen to be able to have a definite time period in which to conduct the comparison for the documents and the ships. By the later half of the 1400s, the great galleys, including the merchant galley to Flanders, had increased in overall size for greater capacity. Lane 1934, 134; 1966, 172. Rossi (2009a, xiv-xvii) mentions two additional texts examining the galley of Flanders: *Ragioni antiche spettanti all’arte del mare et fabriche de vasselli* (dating to 1470-1561) and *Tratto de re navali cavato dall’esemplar di Giavanni Battista Ramusio* (dating to the early 1500s). Due to the date of these documents outside the chosen temporal parameters, these documents will not be discussed in the present study.

Fabrica di Galere

The *Fabrica di Galere* is a Venetian manuscript dated to the mid-16th century that contains 123 folios of text and illustrations on various ships and associated topics.¹¹⁶ The original manuscript was actually titled *Libro di Marineria* (A Handbook on Seafaring); however, Augustin Jal's 1840 publication of portions of this text was titled *Fabrica di Galere*, and this is the name by which this manuscript has been commonly known since the 19th century. During many years the *Fabrica di Galere* was thought to be a compilation of texts by numerous authors, but recently scholars studying the Michael of Rhodes book identified the sole author of the manuscript as the geographer and writer Giovanni Battista Ramusio.¹¹⁷ Ramusio (1485-1557) was a scholar who wrote and studied literature, which was beneficial to his positions as secretary of the Senate in 1515-1553 and the Council of Ten in 1553-1557.¹¹⁸ Even though Ramusio was not a sailor and took part in only a limited number of travels during his career, he was able to collect numerous first-hand accounts of sailors' travels and published them in three volumes entitled *Delle Navigationi et Viaggi*. The first of which was published in 1550. The scholars also associate Ramusio with the *Fabrica di Galere* speculate that he wrote it in the 1520s or 1530s.¹¹⁹

¹¹⁶ The original document no longer exists, but according to Bondioli (2009, 246) two copies of the document are left. One is housed in the Biblioteca Nazionale Centrale di Firenze, codex Magliabecchiano, XIX 7, and the second is in the Austrian National Library codex 6391.

¹¹⁷ Franco Rossi (2009a, xvi), found a page in a copy of the *Fabrica di Galere* crediting Giovanni Battista Ramusio. This implies the original copy was written by Ramusio, and a comparison of samples of his handwriting further supported the theory. See also Rossi 2009a, xi-xxxiv; Hocker and McManamon 2006, 4.

¹¹⁸ Parks 1955, 129-32.

¹¹⁹ Rossi 2009a, xvii.

The first 50 folios in the *Fabrica di Galere* discuss several ships, including a galley of Flanders, a galley of Romania, a light galley, a lateen rigged ship, and a square rigged ship. Sail making, rigging and spars are discussed, although sail making is also mentioned in the galley of Romania section. Supplementary information on the galleys of Flanders and Romania is given after the rigging section. This is followed by folios on an unspecified type of small, oared craft and the dimensions of the *falchoni*, a small craft built by the Venetian Arsenal. The next pages shift from discussing ship construction to the prices of equipment and supplies, such as timber and ironwork. The manuscript then returns to ship construction by describing the rigging of a square rigged ship.¹²⁰ The final folios discuss the tides.

Fabrica di Galere has a total of 15 pages devoted to the galley of Flanders throughout the entire manuscript, which can be found on folios 1 through 13 and 73 through 75.¹²¹ The length of the vessel given is 23 paces and 3 1/2 feet, or 118 1/2 feet. The depth of the ship amidships is 8 feet minus 2 fingers (7 7/8 feet) and 17 1/2 feet wide.¹²² It has 42 frames in the prow, 42 frames in the stern, and 4 amidships.¹²³ The height of the stem is described as being 9 feet at the main wale and 10 1/2 feet at the sheer strake with a 10 1/2-foot rake.¹²⁴ The height of the stern post is 13 feet with a rake of 10 1/2 feet.¹²⁵

¹²⁰ Anderson 1945, 161-2.

¹²¹ Anderson 1945, 161.

¹²² Jal 1840, 31, 35.

¹²³ Jal 1840, 6.

¹²⁴ Jal 1840, 6, 38.

¹²⁵ Jal 1840, 6, 41.

The breadth of the floor is given as 10 feet.¹²⁶ The breadth of the hull, listed at incremental heights, is presented in Table 1. In some cases the original dimension is written as a calculation and in Table 1 can be found within the parentheses.

Table 1. Breadth of hull given at incremental heights¹²⁷

Feet above floor (amidships)	Breadth of hull, original text in parenthesis when calculations were applied
$\frac{1}{2}$	11 $\frac{1}{3}$ feet (12 feet minus $\frac{2}{3}$ feet)
1	12 $\frac{1}{2}$ feet
2	14 feet, 2 fingers
3	15 feet, 2 fingers
4	15 $\frac{7}{8}$ feet (16 feet minus 2 fingers)
5	16 $\frac{1}{3}$ feet
6	16 $\frac{3}{4}$ feet (17 feet minus $\frac{1}{4}$ feet)
7	17 feet, 2 fingers
8 feet minus 2 fingers	17 $\frac{1}{2}$ feet

While translating and comparing the *Fabrica di Galere* and Michael of Rhodes manuscript, it was apparent that these documents are almost identical and are likely copies of a third, unknown original manuscript; this theory will be discussed further at the end of the chapter.¹²⁸ In order to eliminate redundancy within this thesis, the remaining folios from *Fabrica di Galere* will be discussed with the Michael of Rhodes text.

¹²⁶ Jal 1840, 6.

¹²⁷ Supra n. 126.

¹²⁸ Rossi 2009a, xvi-xvii.

Michael of Rhodes' Book

The Michael of Rhodes book contains over 100 folios on various topics including shipbuilding, mathematics, navigation, and astrology. In the book, the author twice identifies himself as *Michalli da Ruodo* (Michael of Rhodes).¹²⁹ Michael of Rhodes was a Venetian seaman who worked his way up from oarsman to *armirao* (assistant to captain) of a merchant galley.¹³⁰ In addition to the aforementioned topics in the book, the author included information on his personal life and his professional career as a mariner. He began writing the book in 1434 and his last entry dates to 1445.¹³¹

The book begins with a section on arithmetic and algebra which is followed by the *curriculum vitae* of Michael of Rhodes. Then there are several folios on astrology and astronomy.¹³² He then lists the orders given by the captain general of the guard fleet in which he embarked, Andrea Mocenigo in 1428.¹³³ The next folios have instructions for navigation, including how to enter ports such as Venice and Sluys, and information on waters, tides, winds, and crossings. This is followed by folios on sail-making and shipbuilding; the shipbuilding topics and folio pages will be described below. Between the sail making and shipbuilding folios are sections on almanacs and the lunar-zodiac table. In addition to astronomy, another digression from the sail and shipbuilding topics

¹²⁹ Stahl 2009a, 272-273 translates folio 90-2b as “I, Michael of Rhodes, shall write below about the time I came to Venice.” Stahl (2009a, 2:570) also translates folio 204a “I, Michael of Rhodes, received the steelyard by special grant from our Signoria on January 28, 144[5].”

¹³⁰ Stahl (2009b, 91) notes the *armirao* assists the captain in commanding the entire fleet and this position is the highest rank a non-noble man can obtain.

¹³¹ Long 2009, 2,-4.

¹³² Rossi 2009a, xii.

¹³³ Long, 2009, 20-21.

within the shipbuilding section is an illustration of Michael of Rhodes' coat-of-arms. The coat-of-arms appears to have been designed by Michael of Rhodes and is not official due to his non-noble status. Prayers, rituals and magical formulas follow the shipbuilding section. More mathematical problems follow as well as an image of St. Christopher – the patron of voyagers – which is followed by a single folio with a list of materials and men needed to build a galley of Flanders. The book ends with portolans, written by different authors, and finally, the last wishes of Giovanni da Drivasto, a sailor that probably had Michael's book when he died, near Cyprus, in the last quarter of the 15th century.

Since the shipbuilding text is such a large section of the manuscript, it is worth examining how it is organized. As already mentioned, the first pages are about sail making, specifically lateen sails. After a digression to astronomy and astrology, Michael of Rhodes describes five vessels: three galleys and two round ships. While they are discussed to different extents, each is organized in the same fashion. First the hull measurements are recorded starting with the principal dimensions (overall length, height and breadth amidships) followed by specifications for the bow, stern, and frames. After the hull measurements, Michael of Rhodes provides information on the rigging, sail, and ship's equipment. The galley of Flanders is the first of five ships examined, covering 25 pages of hull measurements and information on the masts, rigging, and equipment of the galley. Within these 25 pages, 18 pages contain either a full-page illustration or drawing. The galley of Romania is the next vessel reviewed and it covers 17 pages with only nine

pages of illustrations. The last galley is the *galia sotil* (light galley), which, unlike the two galleys described above, it was a war galley and not a commercial galley. Fourteen pages are devoted to this galley. The hull measurements are on the first nine pages, with six containing illustrations, and the rigging and equipment is on the remaining five. The hull measurements appear to be missing key components that Michael of Rhodes traditionally lists first; therefore it is thought that the first two pages are missing.

Following the description of the galleys, Michael of Rhodes describes two commercial sailing ships: *nave latina* and *nave quadra*. There are eight pages for the *nave latina* (which is a round ship with lateen sails) with approximately two pages for the hull measurements and the remainder for the equipment and rigging, including three ship's boats. Several pages leave room for illustrations that were never completed, including the final illustration showing the completed vessel (at sea) under sail. Twenty-nine pages are dedicated to a description of the *nave quadra*, a round ship with square sails. Less than two pages are devoted to the hull's measurements, followed by 27 pages of equipment and rigging, once again including two ship's boats. As with the *nave latina*, there are figure titles and spaces for illustrations, but most were not completed; in the case of the *nave quadra*, only one illustration was finished. Also of note in this section is a description of the combination of one square sail and one lateen sail on the two masts of the sailing ship.¹³⁴

¹³⁴ McNeill (1974, 50) notes that this practice of utilizing both the lateen and square sail began shortly before 1300.

The (Michael of Rhodes) book describes the galley of Flanders' hull length as 23 paces, 3 1/2 feet, or 118 1/2 feet. The floor is 10 feet and the breadth is 17 1/2 feet. The deck's height at amidships is 7 7/8 feet (written as 8 feet minus two fingers.)

The stem height given at the main wale is 10 1/2 feet with a rake of 10 1/2 feet. The stem height to the sheer strake is 9 feet, resulting in a height of 1 1/2 feet between the sheer strake and main wale. The stern height is 13 feet with a 10 1/2-foot rake. There are 4 frames amidship, and 42 whole molded frames located fore and aft of these central frames, for a total of 88 frames. The floor is 10 feet wide and the breadth of the ship at incremental heights from the floor is identical to those given in *Fabrica di Galere* (see Table 1).

As previously noted, the texts in Michael of Rhodes and *Fabrica di Galere* are similar and for that reason the following folios will be discussed together.¹³⁵ The text of *Fabrica di Galere* is taken from Jal's transcription of the original text in his book *Archaeologie Navale, Volume 2*.¹³⁶ In this case study, I first compared the texts in their original Italian, looking for discrepancies and omitted words. My translation of the Italian texts is presented below and I used the following resources: Settembrini 1879; Antruther and Settembrini, 1804; Long et al., 2009; Jal, 1840 (both the French translation and his glossary); and Alertz, 1995, 160. Since the focus of this thesis is to gather information

¹³⁵ The sources for the Michael of Rhodes manuscript text are *The Book of Michael of Rhodes, A Fifteenth-Century Maritime Manuscript Volume 1: Facsimile* and *Volume 2: Transcription and Translation*.

¹³⁶ Long et al., 2009, volumes 1, 2; Jal 1840, 6-15. Since Jal's is a transcription of the manuscript and not a facsimile of the original, some of the discrepancies could be due to transcription error.

on the dimensions of the ship and not the translations of the manuscripts, the information has been compiled into sentences, and the reader can refer to the verbatim translations in the Jal or Long texts mentioned above.¹³⁷ After comparing the two texts, the Italian transcriptions were found to be almost identical, except for a few missing lines; however, it was the translations of the Italian words or phrases in the respective sources that differed. In some cases, a suitable English equivalent word has yet to be found or agreed upon; in others, the word or phrase has more than one plausible meaning. For the translation below, the most common terminology from the resources was used, and where no corresponding was found, the word or phrase is written in italicized Italian with the possible translation(s) in the footnotes. Since the basic dimensions (length, breadth, and depth) found in each manuscript are given above, my translation begins with folio 136a of the Michael of Rhodes book.¹³⁸

The piece of wood located at the join of the stempost to the keel rises 1 finger and from the top of the main wale to the top of the sheer strake is 1 1/2 feet.¹³⁹ The stern post is 13 feet high and rakes 10 1/2 feet. The aft piece of wood located at the join of the sternpost to the keel is 1 1/2 finger. From the main wale to the top of the transom is 3 1/8 feet.

¹³⁷ The structuring of sentences primarily removed the numerous sentence fragments, mostly beginning with “and.” The subject, adjective, verbs, and measurements of the sentence were not removed.

¹³⁸ Jal 1840, 6. Jal does not include the page or folio numbers from the original document in his transcription.

¹³⁹ Stahl (2009a, 419) translates this piece of wood as a compass timber at the coulter mark.

Measuring at the forward end frame, from the keel to the main wale is 7 minus 1 finger, measuring vertically. At the 18th frame forward, the distance from the top of the keel to the top of the main wale is 6 1/3 feet, measuring vertically. The distance from the top of the keel to the top of the main wale has a measurement of 7 feet minus 1/4foot at the 18th frame aft, measuring vertically. The keel to the main wale at the aft frame is 8 feet minus 1/3 foot. From the main wale to the sheer strake is 1 1/2 feet when measured at the prow tail frame, along the futtocks. Measuring from frame 18, from the main wale to the top of the sheer strake is 1 1/2 foot, on the forward site along the futtocks.¹⁴⁰ Amidships, the main wale to the sheer strake is 1 1/2 feet along the futtocks. Measuring at the 18th frame aft, the distance from the top of the main wale to the sheer strake is 2 minus 1/4feet, along the futtocks. At the aft frame from the top of the main wale to the sheer strake should be 2 1/6 feet, along the futtocks.¹⁴¹

Measuring the edge of the sternpost to the edge of the rudder bracket is 5 minus 1/4feet. It opens 4 minus 1/4feet to the stern partition to the inside of the partition.

¹⁴⁰ Neither text indicates if the 18th frame is fore or aft; however, it is thought to be the 18th frame forward since the next line in the Michael of Rhodes text is for the distance from the main wale to the sheer strake at the 18th frame aft.

¹⁴¹ The measurement is written as 2 1/2 1/3 feet.

The forward bulkhead is 8 1/8 feet from edge of stem to middle and end, measuring along the sheer strake.¹⁴² The aft bulkhead is 10 minus 1/3 feet from edge of transom to middle of yoke (along sheer strake). The measurements between the deck beams should be 2 minus 1/4 feet long. The measurement aft of the yoke, from the sheer strake to the longitudinal stringer is 1 foot.¹⁴³ Measuring the deck beam's neck from the sheer strake to the longitudinal stringer is 1 minus 1/4 foot.¹⁴⁴

The mast step is 18 beams forward of the yoke and is made of 8 half beams. The mast step is at the forward beam (or coaming) of the carpenter's hatch. The hatch is 4 beams wide. In the aft coaming, from the hatch there are 6 beams, including the forward yoke. The aft coaming of the first mate's hatch, there is a half beam at the half beam that goes to the forward coaming. The hatch opens to the stem and stern 4 feet. The aft coaming of the hatch of the aft compartment is at the 11th deck beam and the forward coaming is at deck beam 13, including the yoke. The mast step socket is 1 1/2 feet wide.

Measuring from the middle of the galley the gangway is 1 1/8 feet. At the prow the gangway is 2 minus 1/3 feet, measuring along the inside of the gangway. The

¹⁴² The measurement is written as 8 1/2 1/4, or 1/2 of 1/4.

¹⁴³ The longitudinal stringer is the translation Stahl (2009a, 420) gives for the word *bandolina* or *bandolina*. Jal (1840, 579) translates it as a board.

¹⁴⁴ The deck beam's neck is a beam that comes off the deck to support the outrigger. See Alertz 1995, 160 and Stahl 2009a, 420.

mast step is at the forward frame #22. From the bow to the beams of the upper deck the gangway is 2 minus 1/6 feet and it is the same at the middle as the bow.

At the stern, from the top of the deck planking to the inside top of the edge of the gangway is 2 feet. Measuring from the outside top of the gangway to the deck is 4 feet and along the outside edge of the gangway to the inside of the plank below the outrigger is 9 feet, as with the bow and stern.¹⁴⁵ Measuring from the outside of the plank below the outrigger to the outside of the outrigger is 1 1/2 feet forward and aft. If a line goes from the bow to the outrigger the line will be 2 fingers above the gangway.¹⁴⁶

Measuring from the middle of the galley to the top of the gunwale is 1/4 foot above the gangway. Measuring at the stern, the top of the gunwale is 1/8 foot lower than the top of the sides of the gangway. The forward yoke to the first thole pin is 1 1/2 feet and from the aft yoke to the first thole pin is 2 1/3 feet.¹⁴⁷

Measuring from the first thole pin position to the second thole pin position is 3 1/2 feet minus 1 finger, and it goes in this order to the stern. From the first thole pin position to the third thole pin position is one palm and when the bench is

¹⁴⁵ The plank below the outrigger is translated from *banda*, and there is no known English name for this plank according to Stahl (2009a, 420). See also Alerzt 1995, 160.

¹⁴⁶ The line could be translated as ruler; however, Stahl (2009a, 421) translates it as a string line, likely because rulers were not long enough to stretch the length of the vessel. Jal (1840, 49) translates the word as ruler.

¹⁴⁷ Alerzt (1995, 149) writes that the galleys were set up with three rowers, each with their own oar, all on one bench. The man positioned closest to the gangway is the *pianer*, with the *postizzio* being the middle man, and the *terzicchi* or *terzarolo* is the man along the edge of the ship.

placed there, the string line is on the gunwale position. The bench is 1/4 foot from the string line at the gangway. The bench is 3/4 foot away from the string line at the bench stanchion.¹⁴⁸ The bench stanchions are 2 feet high and extends forward of the yoke 1/3 feet and extend aft of the yoke 1/6 feet. They extend 2/3 feet above the midships deck beams, along the plank below the outrigger. The galley has a curvature of the beams (camber) of 1/6 foot.¹⁴⁹ Measuring the outside of the sternpost to the beak is 4 feet.¹⁵⁰ From the beak to the stern partition is 5 feet. Measuring from the sheer strake to the bottom of the cavity of the figurehead is 3 (feet) minus 1/6 feet.¹⁵¹ The galley of Flanders is 19 paces and 3 feet long along the keel. The forward tail frame is 7 minus 1/8 feet from where the keel meets the stempost and the aft tail frame is 9 1/4 feet from where the keel meets the sternpost.

The text then switches a discussion of how to set up the framing ribbands, which are timbers temporarily used to set the frames until the ship's exterior planking is attached.

Measuring along the garboard strake, from the forward end of the keel to the framing ribbands of the bilge stringer is 4 1/2 feet. From the framing ribbands of the bilge stringer to the middle framing ribband is 4 minus 1/4 feet along the

¹⁴⁸ This sentence was not found in Jal's (1840) transcription of the *Fabrica di Galere*.

¹⁴⁹ The text is 1/2 of 1/3 of a foot.

¹⁵⁰ Stahl (2009a, 422) translates *spironzello* as a small projection at the stern. Jal (1840, 51) translates it as beak. See also Alertz 1995, 155, 159.

¹⁵¹ *Chavriola* is translated by Stahl (2009a, 423) as figurehead, while Jal (1840, 52) translates it as forked rafters.

garboard strake and measuring from the middle framing ribband to the upper framing ribband is 5 feet minus 2 fingers along the garboard strake. Measuring at the forward tail frame, the bilge stringer framing ribband is 1/3 foot below the bilge stringer. Measuring from the top of the bilge stringer to the middle framing ribband is 3 minus 1/3 feet, measuring along the futtocks and the middle framing ribband to the upper framing ribband is 4 1/2 feet, along the futtocks. From the aft end of the keel to the top of the framing ribbands of the bilge stringer is 3 1/8 feet measuring along the garboard strake.¹⁵² Measuring from the bilge stringer framing ribband to the upper framing ribband amidships is 5 feet and 2 fingers (measuring) along the garboard strake. From the middle framing ribband to the upper framing ribband is 6 1/2 feet, measuring along the garboard strake. Measuring at the aft tail frame, the upper edge of the bilge stringer framing ribband is 3/4 foot lower than the mark of the bilge stringer.¹⁵³ Measuring from the top of the bilge stringer framing ribband to the middle framing ribband is 3 minus 1/3 feet along the futtocks and measuring from the top of the middle framing ribband to the upper framing ribband is 5 1/2 feet, measuring along the futtocks. At the midship frame, the framing ribband at the bilge is 1 palm below the bilge stringer and this same dimension will be seen at the stern and at the stem.

¹⁵² This sentence is duplicated in the *Fabrica di Galere* transcription. Jal (1840, 55) makes note of the duplication in his translation and states that it is likely the error of the author.

¹⁵³ The measurement was written as “one quarter and half of a foot.”

The next pages of both manuscripts contain several pages of illustrations with dimensions. Since these next three folios were important for creating the ship model, copies of the illustrations can be found in Appendix B. The illustrations include the forward tail frame and then the aft tail frame. The next page contains diagrams of the bow and stern. This is followed by a page illustrating *morelli*, a page showing the breadth amidships at incremental heights, and then two additional pages illustrating *morelli*.¹⁵⁴

The next section in Jal's transcription of the *Fabrica di Galere* describes the materials and men required to build a galley of Flanders. In the Michael of Rhodes book, this section is found at the end of the book in folio 202b. Both texts match each other and the translation is as follows:

This design of the galley of Flanders needs wood to construct it, and first are timbers that are bent for the futtock and the floor timbers and half timbers, at the stern and as the stem. It will need 380 pieces of wood.

It needs another 140 oak timbers that are straight for the keel bilge stringer, sheer strake, deck beams, deck stringers, keelson, ceilings, mast steps, boat

¹⁵⁴ Since the *morelli* were not used in creating the 3-D model, only the breadth illustrations are included in Appendix B; see Long et al. 2009, Vol 1 for the facsimiles of the *morelli*. *Morelli* were units of measurement used for dimensions. Bondioli (2009, 250) describes how shipwrights would use rods with marking of these units, like a ruler. In the manuscripts they are illustrated as rectangles, at scale.

beams, bulwark rails, outrigger brackets: and they need to be 240 and 26 feet long.¹⁵⁵ They need a thickness of 4 feet each.

One needs for the aforementioned galley 280 oak timbers of large size that are 1/4 of a foot thick. And it needs 36 planks of larch with a breadth of one foot or one palm for the mortising inboard and for the outrigger and gangways. Each one of these boards needs to be 8 paces long. One needs 18 planks of fir that are 8 paces and 1 foot for the plank on the outrigger and side planks for the gangways and cleat and benches.¹⁵⁶ And it needs 50 pieces of fir for the gutters and morti and stanchions, rowing stretchers, the steps, and poles.¹⁵⁷ And it needs another 300 fir planks for the hatch coamings, ceiling boards and compartments below deck.

It needs 500 master sawyers for the galley. And it needs 1000 carpenters. And it needs 1300 caulkers to drill, caulk and pitch. And it needs 8 thousand pounds of iron for spikes, pins, clamps, cleats, pintles, and rudder pintles. And it needs 3000 pounds of pitch. And 3000 pounds of oakum.

¹⁵⁵ Jal (1840, 57) notes that these specifications are likely incorrect because 24 or 26 feet long makes more sense than 240 and 26 feet long.

¹⁵⁶ The 1 foot likely indicates the width of the 8 paces-long planks, but it is possible that the length of the plank is 9 feet long.

¹⁵⁷ *Morti* was unable to be translated, but is thought to be a timber.

At this point, the order of the subjects within the manuscripts matches up again; however, both manuscripts are missing words from the next section.¹⁵⁸ Noticeably, the same words are missing from both documents, further supporting the case that the *Fabrica di Galere* is a copy of Michael of Rhodes's book.

The galley of Flanders needs one mast of 14 paces. It should be 7 palms around and a block mast that is 12 feet long.¹⁵⁹ The block mast will need to be 1/5th as wide as it is long. And it will also need a lateen yard that is 9 paces. It needs to be 4 3/4 palms around and 3 3/4 feet around when the two parts of the yard overlap.¹⁶⁰

It needs one middle mast that is ___ paces long and it needs to be ___ feet around and the block mast should be ___ paces and ___ feet and ___ feet across. The yard is ___ paces for the middle mast ___ and it needs another ___ feet. It needs one upper spar of the lateen yard of 14 paces and it needs 3 2/3 palms around, as it is seen in the figure.

The galley of Flanders needs 1 boat ___ paces long and ___ feet and its keel is ___ feet and its depth is ___ feet. It has a beam of ___ feet and a floor of ___ feet. The

¹⁵⁸ The missing words are indicated by underlines.

¹⁵⁹ The term block mast is from Stahl's (2009a, 433) translation of *cholexe*. According to Pryor (1982, 286), the *cholexe* or *cholzexe* or *choxele* was a spar that was scarfed to the top of the mast with two pulleys to haul the lateen yard up the mast.

¹⁶⁰ The yards, especially the lateen yards, were two spars that were scarfed together.

galley needs a skiff ___ feet long and it has a depth of ___ feet and a beam of ___ feet. It is ___ in the floor and its keel should be ___ feet, as you will see here.

Ships Boat (caption)

This is the rigging the galley of Flanders needs for large and small masts and rigging for repairing and rigging for the lateen yard. It needs 5 hemp cords, each 70 paces long, weighing 10 pounds per pace and the total for all 5 is 3,500 pounds.¹⁶¹ The aforementioned galley must have 5 buoy ropes each 70 paces long, weighing 4 pounds per pace, all weighing (a total of) 1,400 pounds. It needs one prow rope (headfast), it needs to be 80 paces long at a weight of 5 pounds per pace, for a total weight of 400. It needs 1 sheet of 18 paces with a weight of 10 pounds per pace. It needs 2 halyard ties 14 paces long, weighing 10 pounds per pace. It needs 2 backstays or vang 45 paces long, weighing 4 pounds per pace. It needs 2 halyard tackle falls 70 paces long, weighing 4 pounds per pace.¹⁶² It needs 2 mast tackles 70 paces long weighing 4 pounds per pace.

It needs 2 rudder tackle falls 5 paces long, and 7 rudder tackle falls 4 1/2 paces long, each weighing 6 pounds per pace. It needs 1 amo 50 paces long, weighing

¹⁶¹ The transcription by Jal (1840, 12) gives the weight per pace as 70, which does not make the total for the 5 ropes 3,500 pounds. He does not note of this error (1840, 66). The Michael of Rhodes version is used here because it gives 10 pounds per pace, thus making the 3,500 pound total correct.

¹⁶² Jal (1840, 68) translates the word *gomene* as hemp cables, and Stahl (2009a, 435) translates it as halyard tackle falls.

4 pounds per pace.¹⁶³ It needs 2 funde 36 paces long, weighing 2 pounds per pace.¹⁶⁴ It needs 1 lateen tackle ___ paces long weighing 2 pounds per pace. It needs an orza poza 36 paces long, weighing 2 pounds per pace.¹⁶⁵ It needs 2 orza puopa 20 paces long, weighing 4 pounds per pace.¹⁶⁶ It needs 1 tackle, used to haul the yard's lower end to the mast when changing tack, of 20 paces the same weight as the stern lateen tackles. It needs 1 pendant for the backstay of 13 paces, weighing 6 pounds per pace. It needs 1 pendant for the tackle of 3 paces, weighing 4 pounds per pace. It needs 1 sheet of 20 paces, weighing 7 pounds per pace. It needs 4 small ropes of 3 paces, each one weighing 1 1/2 pounds per pace.¹⁶⁷

It needs one parrel tackle line 40 paces long, weighing 2 1/3 pounds per pace. It needs two shrouds of 40 paces, each weighing 2 1/2 pounds per pace. It needs pozatrello of 25 paces, weighing 4 pounds per pace.¹⁶⁸ It needs a yard lift of 6 paces, weighing 4 pounds per pace. It needs 1 montaniana of 13 paces, weighing 4 pounds per pace.¹⁶⁹ It needs a fall for the halyard, 120 paces long, weighing 2 1/2 pound per pace. It needs a master tackle of 12 paces, weighing 2 1/2 pounds

¹⁶³ Stahl (2009a, 435) was unable to find a translation for *amo*, which is a type of tackle. Jal (1840, 69-70) translates *amo* as a tackle securing the yard to the mast.

¹⁶⁴ Stahl (2009a, 435) could not define a *funde*, except to note that it was a tackle.

¹⁶⁵ Stahl (2009a, 435) was unable to determine the translation for *orza poza*, except that it was a tackle. Jal (1840, 70) translated it as *l'orcipoggia*, which is the rope fastened to the starboard of a ship in order to stretch the sail when there is too much wind. Montucci, 1818, 285.

¹⁶⁶ *Orza puopa* is translated as a stern sheet according to Jal (1840, 71), but Stahl (2009a, 437) does not have a translation for this phrase.

¹⁶⁷ Stahl (2009a, 436) describes these small ropes as lashings located at the scarf of the two spars of the yard.

¹⁶⁸ None of the resources provided a translation for *pozastrello*. It is likely a type of tackle.

¹⁶⁹ None of the resources provided a translation for *montaniana*. It is likely a type of tackle.

per pace. It needs 1 lashing for master tackle of 8 paces, weighing 10 pounds per pace. It needs 1 chagnola of 36 paces, weighing 2 1/2 pounds per pace.¹⁷⁰ It needs 7 chivali shrouds per side of 8 paces, each weighing 4 pounds per pace.¹⁷¹ It needs 7 shroud tackle falls 9 paces long, each weighing 2 1/2 pounds per pace. It needs 2 mooring ropes of 40 paces, weighing 4 pounds per pace.

Coiled rope. (caption)

Mainsail and mizzen sail below. (caption)

The galley of Flanders needs 5 anchors, they should weigh 120 pounds each, and the total of all 5 is 600 pounds. It needs two painters for the flutes. It needs 2 painters for the rings. Also it needs 2 ropes with hooks for the boat. And these anchors, you can see, will be designed similar in weight and painters.

Anchors (caption)

On the page we made this galley of Flanders with sail because it is complete.

Galley under sail (caption)

¹⁷⁰ None of the resources provided a translation for *chagnola*. It is likely a type of tackle.

¹⁷¹ None of the resources provided a translation for *chivali*. It is likely a type of tackle.

If you load the Flanders's galley of Venice with pepper and ginger you will need three pints of ballast and if you load with wine you will need 2 pints of ballast.¹⁷² And because the galley of Flanders or London needs to stow wool, it needs to take from Venice 120 planks, and it needs one stowing rope of 50 paces weighing 10 pounds per pace, and it needs 1 spare rope of 20 paces weighing 8 pounds per pace.

It needs 1 coil of rope of 50 paces weighing 2 1/2 pounds. And from these, 2 rizade dela stella of 8 paces 1, and for 2 deck friny de chaval de bocha is 9 paces 1, and for 6 ropes for hauling planks.¹⁷³ It needs 1 coil of rope of 70 paces weighing 1 1/2 pounds per pace for 3 rope bundles. Each ones is 9 paces long and the mantixello is 8 paces and the rest are spars for these.¹⁷⁴ It needs 2 coils of small ropes of 50 feet 1 for planks slings, shoud ropes, chests, vananti, and pins.¹⁷⁵ It needs 1 capstan 3 1/2 paces long 4 feet. It needs 2 double pulleys, one per side and it needs one tackle on the end of the beam, which is 5 paces long and 3 feet wide. Its block mast should have pulleys.¹⁷⁶ It needs 2 stelle each 4 feet.¹⁷⁷ It needs 2 chests, each 3 feet. It needs 2 vananti, each 3 feet.¹⁷⁸ It needs

¹⁷² It is uncertain what a pint of ballast equates to, but Stahl (2009a, 439) just translates it as a load of ballast.

¹⁷³ The *rizade dela stella* translates to *star tackles*, which Stahl notes is a part of the loading gear. The *friny de chaval de bocha* translates to horse's mouth, is also loading tackle according to Stahl (2009a, 439).

¹⁷⁴ The translation for *mantixello* is unknown to Stahl (2009a, 439). I was unable to find Jal's translation of the word.

¹⁷⁵ Again, *vananti* was unable to be translated.

¹⁷⁶ The Michael of Rhodes book says there are two pulleys on this block tackle and Jal's transcription does not state a number of pulleys.

¹⁷⁷ Supra n. 173.

¹⁷⁸ Supra n. 175.

one chaval of bocha of 12 feet.¹⁷⁹ It needs 6 chavali for the beam. Their tackles are held by the shrouds.¹⁸⁰

The pewtrell should have prongs, one prong across and prongs on the sides and bottom.¹⁸¹ It needs 4 pewtrells forward of 10, 11, 12 1/2, 13 feet. At the first prong, 11 sacks, one with a twist, the second, 12, the third, 13, and the fourth, 14. The pewtrell for the stern, the first of 13 feet, the second is 13 1/2 feet, the third 14 feet, and the fourth 14 1/2 feet. At the first 14 sacks, the second 15 sacks, the third 15 sacks, the fourth is 15 sacks, and the rest is however you think looks best.

The galley needs for stowage, cords for binding the sacks: it needs strope (strip of rope), it needs supports for the beams, for the sides, and the deck. It needs 1 pulley and 2 pins.

Halyard (caption)

Beam (caption)

The galley of Flanders has one stern rudder, which at the pointed end is 4 paces 2 1/2 feet and the neck to the heel in the back is 4 paces 2 1/2 feet. The paddle/

¹⁷⁹ Supra n. 173.

¹⁸⁰ Supra n. 173.

¹⁸¹ Pewtrell is how Stahl (2009a, 441) translated *petural*. He describes a pewtrell as a “temporary crosswise bulkhead used in the storage of sacks of wool.” I could not find a translation of the word by Jal or in the other dictionaries.

blade are 5 feet wide at the base and at the third of the length is 4 feet wide.

(caption)

Rudders (caption)

Galley under sail and oars [This caption is for a different illustration and appears only in only in the Michael of Rhodes book. It is not in the transcription of *Fabrica di Galere*.]

As seen here, both the Michael of Rhodes book and the *Fabrica di Galere* provide an extensive amount of information on the galley of Flanders; by comparison, the book of Giorgio “Trombetta”, the second source in this study, does not have as much information. Being that there are so few documents written about the galley of Flanders, during this period of study, all of them are introduced here, no matter their length. As an ancillary result, they all demonstrate the reliability and/ or the limitations of the textual resources available.

The book of Giorgio “Trombetta” da Modone

The final Venetian treatise that seems to discuss the galley of Flanders is the manuscript written by Giorgio Trombetta, sometimes designated as the *Libro di Zorzi Trombetta da Modone* or according to its more common name, the Trombetta Manuscript. This

manuscript dates between 1444 and 1450.¹⁸² The author identified himself as Zorzi T[ro]mbetta da Modone within the text.¹⁸³ Authors discussing this text have translated Zorzi as Giorgio and the name Trombetta has sometimes been misread as Timbotta. The author has been identified as a musician who played the trumpet on Venetian ships.¹⁸⁴ The manuscript is comprised of 64 folios on various topics. Folios 2a-8a discuss music, which are followed by three folios on mathematics and five on sail making and rigging (folios 12a-16a). Folios 16b-19b deal with astronomy, and 20a-23a is a copy of a letter from someone in India to the Pope in 1441. There is little information in folio sections 23b-27a because these pages contain fragments of personal accounting information, or are completely blank.¹⁸⁵ Shipbuilding information is found mainly in folios 27b - 28b. After a section on engineering, folios 37a through 60b contain disorganized notes on shipbuilding and sail making.¹⁸⁶

Ships discussed in the manuscript are the *galia sotil* (light galley), the *galia grosa* (great galley), three different sizes of *fustas* (of 26, 15 and 10 banks), and seven *nave* (ranging from 1000 botte to 200 botte).¹⁸⁷ The galley of Flanders, the galley of Romania, and a light galley are mentioned in folio 44.¹⁸⁸

¹⁸² Anderson 1925, 135-136; Hocker and McManamon 2006, 4; Rossi 2009b, 107.

¹⁸³ Anderson 1925, 135.

¹⁸⁴ Hocker & McManamon 2006, 4; Reith 2001, 82.

¹⁸⁵ Anderson 1925, 135.

¹⁸⁶ Anderson 1925, 137.

¹⁸⁷ Anderson 1925, 147; Reith 2001, 86.

¹⁸⁸ Reith 2001, 86.

The information on the galley of Flanders is limited to basic dimensions. The Trombetta manuscript gives a length of 139 Venetian feet, a beam of 17 Venetian feet, and a height amidships of 8 Venetian feet.¹⁸⁹ The keel length is 23 paces and 3 feet, which equates to 118 feet. The stem has a height of 10 1/2 feet with a rake of 10 1/2 feet and the stern has a height of 13 feet with a 10 1/2 foot rake. Based on these measurements, the full length of the ship would be 139 feet with the stem and the stern posts.¹⁹⁰ The floor measures 10 feet above the keel, amidships. The dimensions are supplemented by two drawings.

Manuscript Comparisons

Descriptions of the hull measurements in the *Fabrica di Galere*, the Michael of Rhodes book, and the *Libro di Zorzi Trombetta da Modone* are very similar, although the most salient difference is the extent of information given. Both *Fabrica di Galere* and the Michael of Rhodes text have numerous pages on the galley of Flanders, listing many standard dimensions, including those used only during construction (framing ribbands), as well as equipment and rigging. The Trombetta manuscript is limited to the basic hull dimensions (length, breadth, depth) and information on the stem and stern posts, including drawings. Inasmuch as each manuscript is different in its non-shipbuilding content and length, it is not strange that the Trombetta has less information on the galley of Flanders, though this is problematic for the purpose of comparing data in the other treatise. The limited specific information on the galley may be explained by

¹⁸⁹ Anderson 1925, 144. Note the overall length is not written out in the text.

¹⁹⁰ The total length is derived from adding the keel length of 118 feet to the 10 1/2 foot-rake of the stem and stern at each end.

Trombetta himself in a statement on folio 12b regarding rigging. Anderson's translates the statement as follows: "Note that nobody can rig any ship or lateener if first the man does not know how the measurements of the ship, for a ship is better rigged by seeing the measurements of her beam."¹⁹¹ Because shipwrights built and designed the ship and rigging from rules and ratios, it was assumed that the reader would not need additional measurements. The reader would know the relationships between such things as the length of the hull to the length of the mast and if the mast is a certain length, then the yard would be a known fraction of it.¹⁹²

As previously noted, none of these manuscripts is likely to be the original source for these ship descriptions. The Michael of Rhodes book is the oldest of the three, but does not appear to be the original text. The *Libro di Zorzi Trombetta da Modone* is not a copy of the Michael of Rhodes book, while they share similarities in some topics, including naval architecture, they do not follow the same format or overlap very much.¹⁹³ The Michael of Rhodes's book is carefully organized, while the *Libro di Zorzi Trombetta da Modone* is a bound set of scattered notes on various subjects. Due to the few similarities it is likely that both documents were copied from another unknown text.¹⁹⁴

It is almost certain that the naval architecture and sail making sections of the *Fabrica di Galere* were copied from the Michael of Rhodes book. As we have seen regarding the

¹⁹¹ Anderson 1925, 155.

¹⁹² McGee 2009, 239.

¹⁹³ Rossi 2009a, xvii.

¹⁹⁴ Supra n. 193.

section on the galley of Flanders, the text is almost identical and the order of the topics is similar. Rossi concludes that the *Raxon de'marineri*, the *Fabrica di Galere*, and the *Trattato de re navali cavato dall'esemplar di G. B. R.* are copies of the Michael of Rhodes book.¹⁹⁵ Subsequently, since the latter two manuscripts are purportedly written by Giovanni Battista Ramusio, Rossi speculates that he had a copy of or access to the Michael of Rhodes book.¹⁹⁶

If that the manuscripts were copied from each other or another unknown source it explains why there are so few differences between them. The biggest difference between all three documents is the length of the galley of Flanders. In the *Libro di Zorzi Trombetta da Modone* the length is given as 139 feet, but both the Michael of Rhodes book and the *Fabrica di Galere* list the length as 118 1/2 feet. In the *Libro di Zorzi Trombetta da Modone* the length is written as “*Longa in cholonbra pasa 23 pie 3,*” which translates as “the keel length is 23 paces and 3 feet.”¹⁹⁷ Both the other documents write “*Et primo la galea de Fiandra e longa da alto passa 23, pedi 3 1/2,*” which translates to “And first the Flanders galley is 23 paces and 3 1/2 feet long.”¹⁹⁸

The difference in length can either be an error in part by the Giorgio Trombetta, or an error in the other two manuscripts, or correct in all three (discussing different versions of the galley of Flanders). It is most likely the *Libro di Zorzi Trombetta da Modone* is

¹⁹⁵ Rossi 2009a, xiv, xv.

¹⁹⁶ Rossi 2009a, xvii.

¹⁹⁷ Alertz 1995, 92 n.98.

¹⁹⁸ Jal 1840, 6; Stahl 2009a, 416.

incorrect, based on the ratio of the breadth to length of the hull. The length gives the approximate ratio of length to beam as 8:1, while in contrast, the ratio for the length in the Michael of Rhodes book is 6.8:1. Light galleys commonly have a ratio as high as 8:1, but based on dimensions given for the great galleys during this period they did not usually have a ratio larger than 7:1.¹⁹⁹ If the length of the ship is an error, it suggests that the author, Giorgio Trombetta, was not familiar with shipbuilding and likely incorrectly copied the information from a primary source.

Between the *Fabrica di Galere* and the Michael of Rhodes book there are few differences. The sentence “*Measurando dal poselexe del choltro al imposture da pope in fino in capo de la maistra de la paraschuxula de essere pedi 3 mesurando per la via del panixelo e 1/8 de pe*” (translated: From the aft end of the keel to the top of the framing ribbands of the bilge stringer is 3 1/8 feet measuring along the garboard strake) is duplicated in *Fabrica di Galere*. Jal notes this duplication in his translation indicating the error is the fault of the author and not Jal, the transcriber.²⁰⁰ The sentence “*E baco lo bancho dala trazuola per mezzo el pe’ del bancho 3/4 de pie*” (translated: The bench is 3/4 foot away from the string line at the bench stanchion) was not within the *Fabrica di Galere* text, but is found only in the Michael of Rhodes book.²⁰¹ The only other noticeable difference in content is the location of the materials and manpower section,

¹⁹⁹ Alertz, 1995, 157 n.98; Lane, 1934a, 236.

²⁰⁰ Jal 1840, 9.

²⁰¹ This sentence translates to: “And the bench is 3/4 foot away from the *string line* at the bench stanchion.” Stahl 2009a, 422.

which is found at the end of Michael of Rhodes's book and not within the galley of Flanders description, as it is in the *Fabrica di Galere*.

Information on the dimensions and construction of the galley of Flanders is limited to a few documents, which were likely copied from the same original source. The authors of the text discussed here were not shipwrights, but their experience with ships and sailing makes them relatively credible. Conversely, since the original source and its author(s) is unknown, the credibility of these copied documents decreases. Research on galleys of the late Middle Ages indicates that the basic measurements of the galley of Flanders given by Michael of Rhodes (and, in turn, the *Fabrica di Galere*) is likely correct. Based on the information in these treatises, the galley would have been 118 1/2 feet long, with a breadth of 17 1/2 feet and a depth of 8 feet minus 2 fingers. These measurements are the basis for the 3-D digital model of the galley of Flanders that will be presented in the next chapter.

CHAPTER IV

3-DIMENSIONAL MODELING OF THE GALLEY OF FLANDERS

The previous chapter looked at the dimensions of the galley of Flanders based on three textual sources, of which two are nearly identical. In contrast, the Trombetta manuscript contains limited and perhaps less reliable information regarding the galley of Flanders. Therefore, only the measurements in the Michael of Rhodes book were used in this chapter to draft the galley of Flanders. A lines drawing was used to generate a 3-D model of the ship in Rhinoceros 5® (Rhinoceros) with the purpose of determining the hull's capacity. Additionally, the initial intent of the 3-D model was to explore how the vessel was loaded, but due to the limited information on where cargo and equipment were placed, this experiment reached a dead end. The limited amount of information on this subject is discussed below.

Creating a 3-D Model

The first step in creating the 3-D model was to draft the molded lines of the galley of Flanders on paper.²⁰² Since the purpose of generating an illustration of the ship in 3-D was to investigate the capacity of the hull, the outrigger, and superstructure were not included in either the lines drawing or in the 3-D model.²⁰³ The lines drawing showed the ship in three views: plan, profile, and breadth.

²⁰² In the moulded lines drawing, plank thickness is not included.

²⁰³ There is limited information on the superstructure and outrigger dimensions. Alertz (1995, 159) contains a lines drawing that includes the superstructure, outrigger, and rigging.

The measurements used to create the lines drawing were taken from the Michael of Rhodes book and as such are identical to the measurements in the *Fabrica di Galere*.²⁰⁴ Due to the limited information in the Trombetta Manuscript, this treatise was not used to re-create the vessel. Despite the extensive list of measurements in the Michael of Rhodes text, it did not provide all of the measurements needed to draft the ship's lines.²⁰⁵ For example, the number of frames is given, but the spacing between the frames is not given as a measurement, but shown as a *morello*.²⁰⁶ In some cases, the missing measurement could be deduced from known proportions or even calculated from other known dimensions, as with the spacing between the frames. If these techniques could not be used, measurements were approximated from documents written about contemporary ships of comparable size. Additionally, information was also obtained from a war galley excavated in Lake Garda, Italy.²⁰⁷ This war galley sunk in 1509, had a length estimated to be 130 feet long.²⁰⁸ Table 2 illustrates the measurements used for the lines drawing and the source of the measurement. The measurements are expressed in Venetian feet and fingers (or digits), where one Venetian foot is equal to 16 Venetian fingers.²⁰⁹

²⁰⁴ Only the Michael of Rhodes book will be cited through the remainder of the chapter, since the nearly-identical *Fabrica di Galere* does not provide additional useful information.

²⁰⁵ Since ships were built by using proportions exact measurements of every component of the vessel was not needed to be written down in order to build a ship.

²⁰⁶ *Morelli* were gauges that represented units of measurement used for dimensions and in the treatises they were rectangular drawings representing the lengths.

²⁰⁷ Scandurra 1972, 209 and Capulli, 2003.

²⁰⁸ Scandurra 1972, 209. Although the warship was longer than the galley of Flanders, the measurements obtained were the width and height of the keel, which are of comparable size and proportion to the merchant galley's dimensions.

²⁰⁹ Alertz 1995, 155. One Venetian paces is equal to 5 Venetian feet which is equal to 7 palms. One Venetian foot is equal to 1.142 English feet or 0.348 meter. Therefore, 1 Venetian foot is equal to 34.800 cm and 1 Venetian finger is equal to 2.175 cm.

Table 2. Measurements of ship components used in lines drawing

Ship component	Measurement	Source of measurement
Length of ship	118.50 feet	Michael of Rhodes
Breadth of ship	17.50 feet	Michael of Rhodes
Depth at amidships	7.875 feet ²¹⁰	Michael of Rhodes
Keel length	97.50 feet	Subtracted rake of stem and stern from length of vessel
Total number of frames	88	Michael of Rhodes
Spacing from center of frame to center of next frame	0.93 foot	$[97.5 - (6 \frac{7}{8} + 9 \frac{1}{4})] / 88$ Subtracted distance from keel to forward and aft tail frames from length of keel, divided by number of frames
Height of Keel	4.50 fingers	Approximate size converted from dimensions from the war galley from Lake Garda ²¹¹
Width of keel	5.50 fingers	Approximate size converted from dimensions from the war galley from Lake Garda ²¹²
Width of each frame	0.25 foot	Approximation based on frame spacing, relationship to width of keel, and number of frames.
Height of each frame	0.375 foot	Approximation, making the height of the frame 1.50 times the width ²¹³

²¹⁰ This measurement is commonly seen as 7 feet 14 fingers within the treatises.

²¹¹ Scandurra 1972, 210.

²¹² Supra n. 211.

²¹³ The Lake Garda vessel's frames had a height 1.3 times larger than the width (Scandurra 1972, 210).

Table 2 Continued.

Ship component	Measurement	Source of measurement
Location of waterlines ²¹⁴	4 feet from bottom of the ship	Initial one arbitrarily drawn on the ink draft, additional one added to digital version at 5.875 feet above keel when calculating water displacement in 3-D modeling programs
Location of baseline	4 feet from center	Arbitrarily drawn on ink draft
Rise of stem	13.00 feet	Michael of Rhodes
Rise of stern	10.50 feet	Michael of Rhodes
Rake of Stem	10.50 feet	Michael of Rhodes
Rake of Stern	10.00 feet	Michael of Rhodes
Location of aft tail frame	9.25 feet from where keel meets sternpost	Michael of Rhodes
Location of fore tail frame	7 minus 1/8 foot (6.725) from where keel meets stempost	Michael of Rhodes

The treatise also shows, through diagrams, how to create the curves of the stempost, sternpost, and midship section. The curves of both the stempost and sternpost in the 3-D model were based on the figures in Folio 139b (Fig. 2; larger version in Appendix B). In

²¹⁴ According to Alertz (1995, 157), there is no documentation of the ship's waterline because this line was not known at construction.

to intersect the vertical line. This angle is then bisected creating a triangle from which points can be drawn and a curve generated.²¹⁵

The curve of the midship frame was based on the dimensions given for the breadth of the midship at incremental heights, seen in Folio 135b of the Michael of Rhodes book and listed in Table 1 of this thesis.

After the lines drawing was completed in ink, it was then scanned to create a bitmap file and imported into Rhinoceros, a program used to create 3-D images. In Rhinoceros the lines on the bitmap were traced and then the entire tracing was scaled to have a single unit in the digital grid equal one Venetian foot (Fig. 3).²¹⁶ In order to reduce data the program had to deal with and make it run faster, the tracings were scaled to one half the actual length of the vessel and then scaled to full size prior to generating the calculations. Once the drawing has been traced in Rhinoceros, the bitmap file can be removed from the background and is no longer needed. The three views in the lines drawing tracing (plan, profile, breadth) were then rotated and matched up to create a frame of the vessel (Fig. 4).

²¹⁵ Alertz 2007, 107-109.

²¹⁶ The lines are scaled by matching up the units set in Rhinoceros with the scale on the lines drawing.

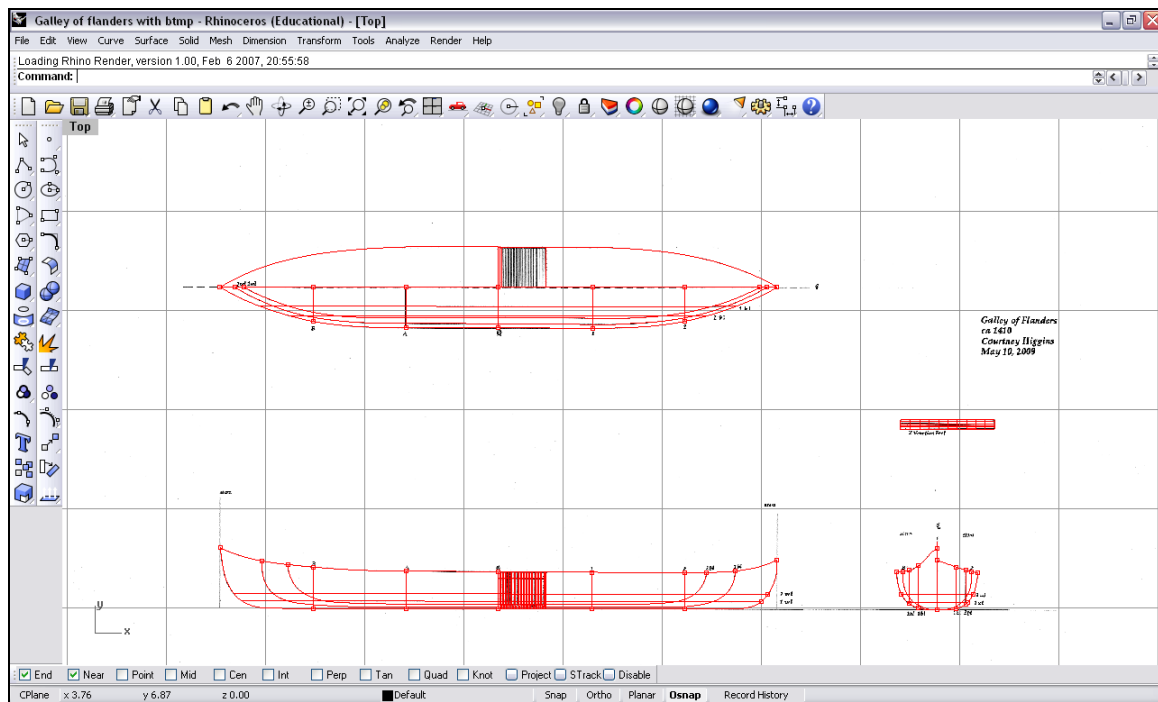


Fig. 3. The bitmap lines drawing in Rhinoceros with traced lines in red.

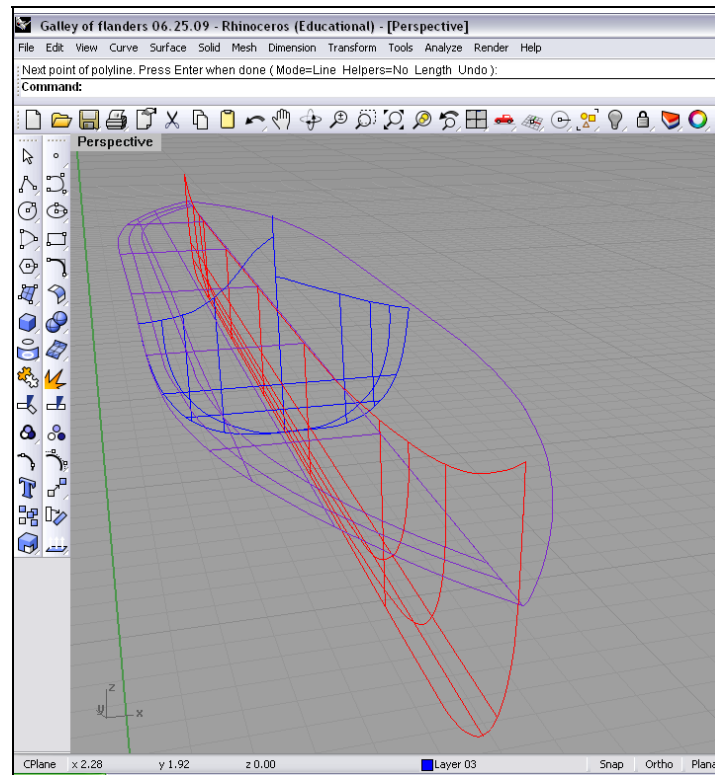


Fig. 4. Three views of the vessel after being rotated and matched up in Rhinoceros.

From this basic frame, a surface could be generated between two or more lines. There are multiple ways to create a surface in Rhinoceros, but for the hull of this vessel “sweep 2 rails” was used because it connected the two lines, while also following the shape of a third curved line. For example, the deck level stringer was connected with the keel, but the surface followed the curve of the cross sectional curve of the midsection.²¹⁷

Unfortunately, when this connection was attempted, the shape of the hull did not follow the midsection curve as closely as one sought. In order to ensure that the intended curve

²¹⁷ The portion from the deck level up to the tops of the stem and stern posts were converted to surfaces last.

was followed closely, the hull's surface was divided by the water lines into three sections. This attempt also proved to give the hull an unnatural shape and did not follow the midsection curve accurately (Fig. 5).

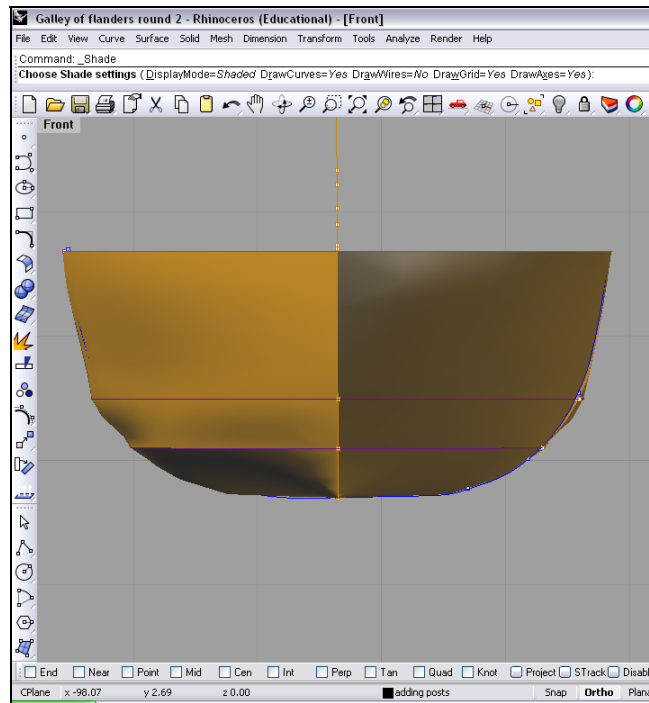


Fig. 5. View of stern using three sections to create the surface.

It was found that with the inclusion of additional sections, the accuracy of the surface to follow the midsection curve improved. Two additional arbitrarily-placed curves were added above and below the two water lines, thus dividing the hull into five sections. When the surface was applied to these five sections, it created a smoother and rounder

hull shape (Fig. 6). Finally, the surfaces from the deck up to the stem and stern posts were created (Figs. 7 and 8).

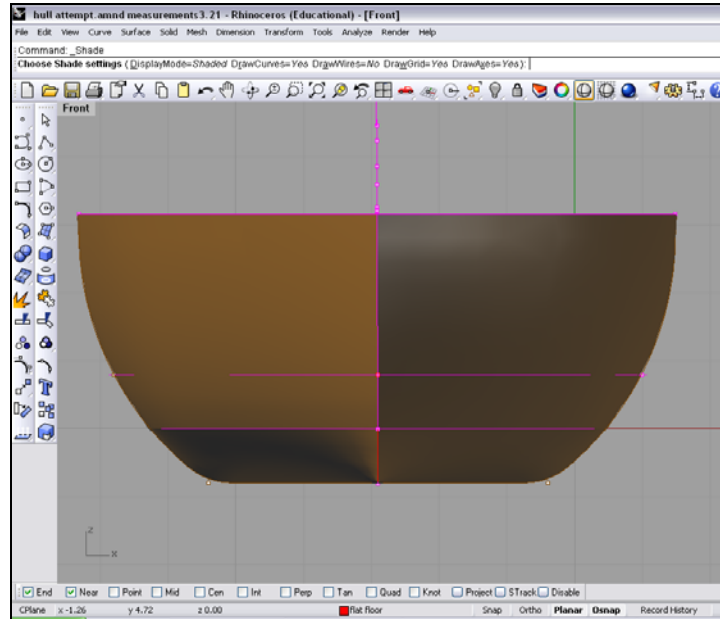


Fig. 6. View of stern using five sections to create the surface.

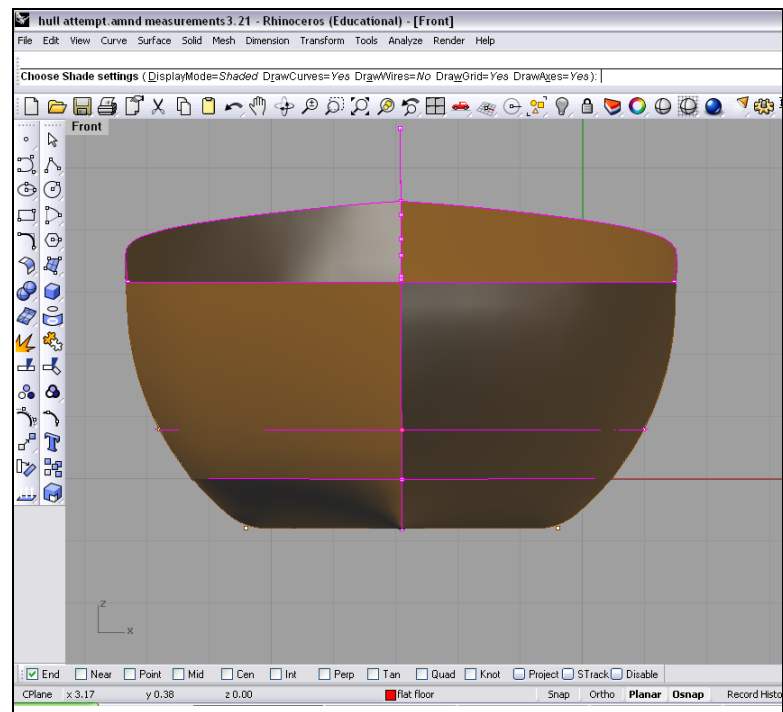


Fig. 7. View of stern.

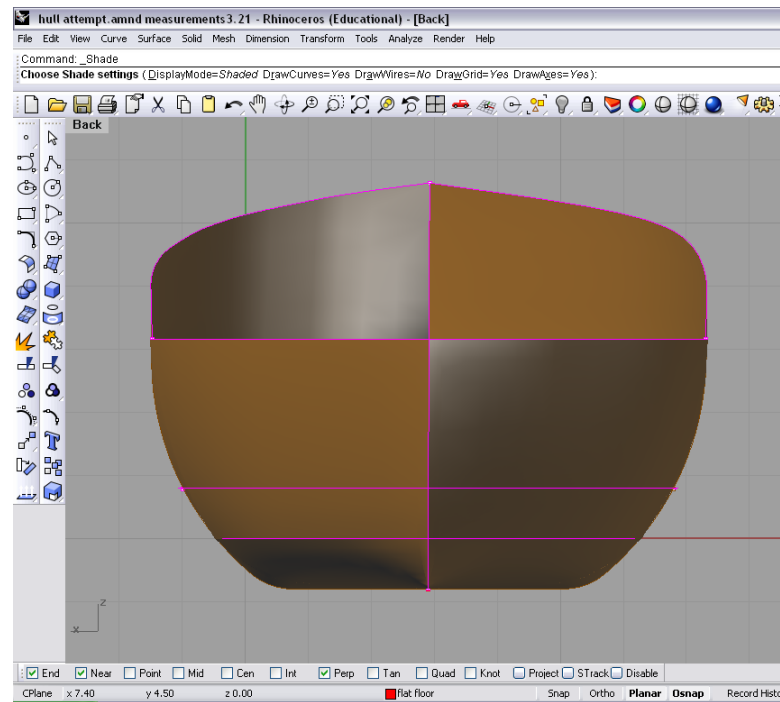


Fig. 8. View of stem.

After the hull's surface was generated, the keel and frames were created (Figs. 9 and 10). Frames were drawn on the lines drawing and were traced in Rhinoceros using the same process described above. According to the treatises, the frames were whole frames, meaning they were carved to extend from the keel to the wale. Each frame was created individually in Rhinoceros by taking the 2-dimensional (2-D) frame, represented as a rectangle from the lines drawing, and extrapolating it into a 3-D rectangle to account for the height of the frames. The 3-D rectangles were then bent to follow the curve of the hull's surface. Shipwrights would have used the *morelli* to shape each frame and these dictated the curve of the hull. Since we begin with a lines drawing showing the curve of

the hull, designing each frame in the same fashion as the shipwrights would have been cumbersome both on paper and in the computer program.²¹⁸ The frames were spaced slightly less than one Venetian foot (0.93 feet) apart, from the center of one frame to the center of the next.²¹⁹ The keel was also made in the same manner as the frames, wherein the 2-D rectangle from the lines drawing was made into a 3-D shape.

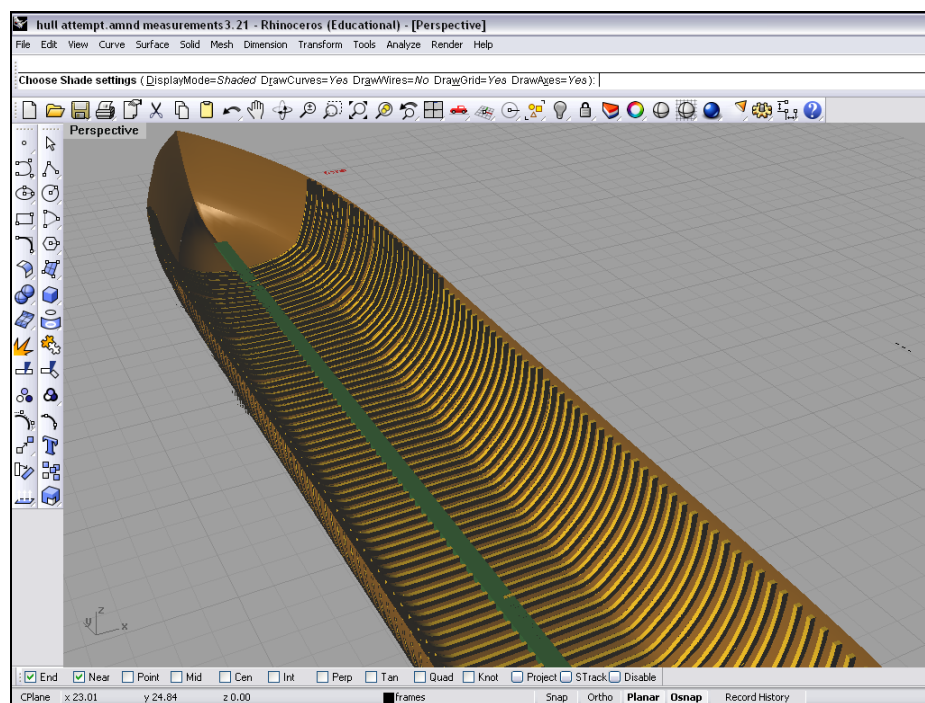


Fig. 9. View of frames (gold) and keel (green) facing toward bow.

²¹⁸ For more information on this process see Alertz 2007 or Bondioli 2009.

²¹⁹ Scandurra 1972, 210. This measurement was based on the war galley from Lake Garda even though that vessel was larger and a different style of galley. Based on the length of the galley of Flanders, the location of the tail frames, and the number of frames, the frame spacing of the galley of Flanders is either the same or very close to that of the war galley from Lake Garda.

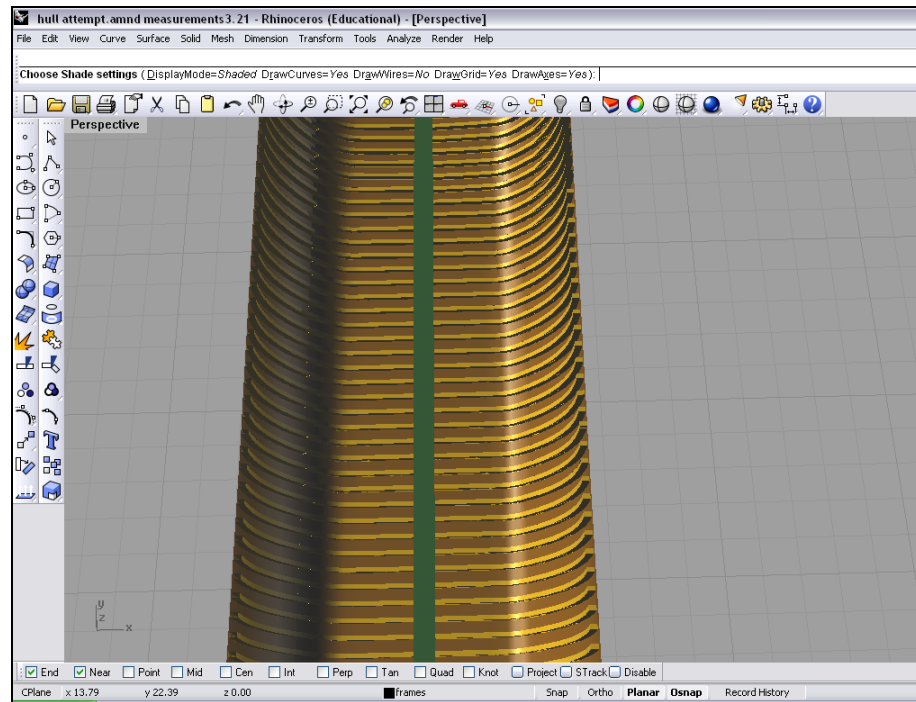


Fig. 10. View of frames (gold) and keel (green) near midships.

The exercise of taking treatise dimensions and generating them in a 3-D model has been done before, and the most relevant example can be found in *Naval Architecture Digitalized Introducing Arithmetic and Geometry into Late Mediaeval Shipwrightry* by Ulrich Alertz.²²⁰ Alertz takes the measurements for a Venetian great galley from Pre Theodoro's notes (circa 1550), and converts it into over 100 pages of LISP-program code.²²¹ A computer-aided design (CAD) program was able to take the code and replicate the vessel in three dimensions. Ultimately, his aim was to demonstrate how

²²⁰ Alertz 2007, 105-127.

²²¹ Alertz (2007, 123) also had the challenge of missing measurements and used other contemporary documents or estimated the measurements in order to fill in the data.

dimensions given in Medieval texts can be used to replicate a 3-D model, and in this case, a model of a vessel under construction in a shipyard. In the article, he did not discuss the logical next step, which is to use these 3-D models to study the ship; including determining how it was laden, rowed, and maneuvered. For the galley of Flanders case study, we will use the 3-D model to look at one feature: the volume of the vessel.

Analyzing the 3-D Model

After creating a model in Rhinoceros, the program has the ability to generate hydrostatic calculations including wetted surface area, volume displacement, and waterline length. The process is as simple as selecting the hull and pressing the auto-generating hydrostatics button. Prior to calculating hydrostatics, three criteria can be applied to the calculation: waterline elevation, symmetric, and longitude. *Waterline elevation* allows the user to determine where the waterline is placed; the vessel's hull bottom must lie along the x-axis for accurate data calculations. *Symmetric* determines whether the whole or half model is used for calculations, and the *longitude* determines the vessel's orientation.

As previously discussed, no waterline was given in any of the treatises, and in my paper draft version the waterline was arbitrarily drawn to illustrate the curves of the vessel. According to Alertz, shipbuilders of the period likely did not consciously identify the waterline during design, but instead knew from experience where a full vessel would sit

in the water; this was likely coupled with meticulously loading the vessel to ensure it was trim.²²² He further explains that Venetian law stipulated that state-owned galleys had to have a freeboard of 2 feet minimum, presumably measured amidships.²²³ Prior to generating the hydrostatics, a waterline elevation was entered of 5.785 feet (depth at midships, 7.785 feet, minus 2 feet). The results of the hydrostatics calculation can be seen in Table 3.

Table 3. Results of hydrostatics calculated in Rhinoceros

	Imperial	Metric
Volume displacement	7736.96 cubic feet	219.1 cubic meters
Center of buoyancy	-0.0218429, 0.0391434, 3.22966	-0.006658, 0.01193, 0.9844
Wetted surface area	2410.53 feet square	734.7 meters square
Waterline length	116.667 feet	35.57 meters
Maximum waterline beam	17.347 feet	5.287 meters
Water plane area	1658.39 cubic feet	46.96 cubic meters
Center of floatation	-0.043451, -0.271897, 5.785	-0.01324, -0.08287, 1.763

²²² Alertz 1995, 157.

²²³ Alertz 1995, 157.

Initially when I generated the hydrostatics in Rhinoceros, the vessel was not aligned on the x-axis, skewing the waterline location and thus receiving bizarre results. In order to find some comparison numbers to the Rhinoceros data, I searched the internet for programs that would generate similar hydrostatic information. After finding a program and utilizing it, I revisited my hydrostatics work in Rhinoceros and found my error. Since the second program I used to generate hydrostatic information also appeared to be a reliable tool, I chose to retain the discussion of this program in this thesis.

The program I found was freeware program called Free!ship that was described to be a modeling program for designing boats.²²⁴ This program is advantageously able to import and use the modeling points already created in Rhinoceros. After importing the data into Free!ship, the galley looked like a points version of the hull surface created in Rhinoceros (Fig. 11).²²⁵

²²⁴ Links to the program and project home page are found at <http://sourceforge.net/projects/freeship/>

²²⁵ Free!ship only required the port half of the vessel, so the hull was bisected in Rhinoceros and saved separately prior to importing into Free!ship.

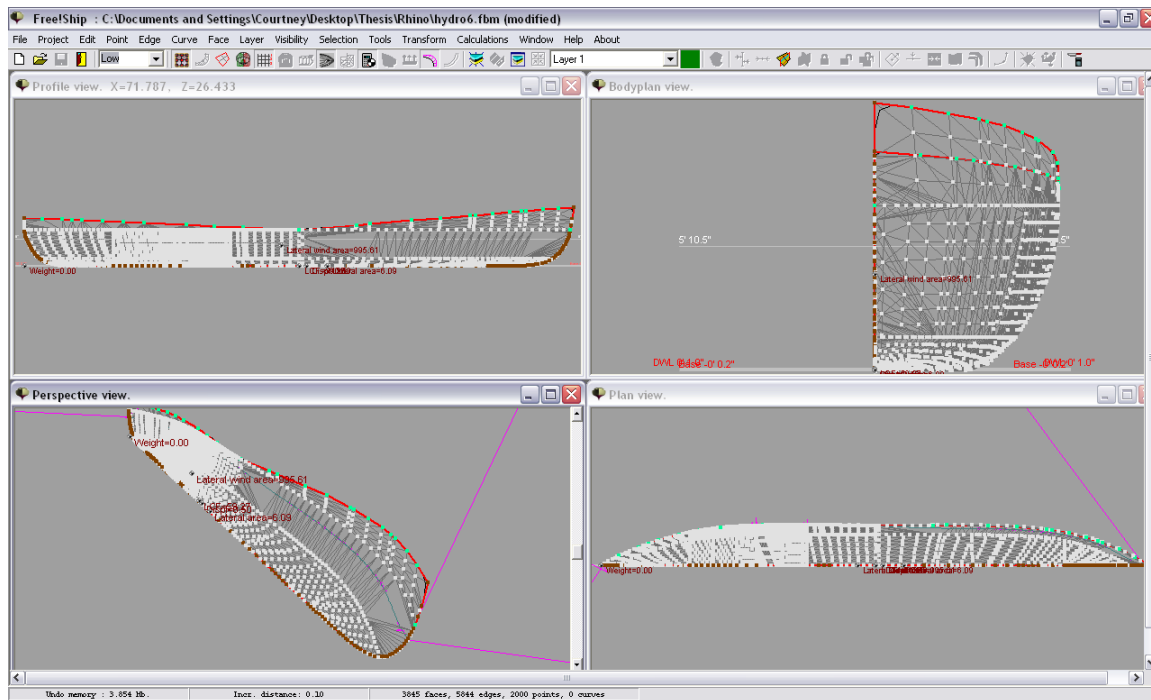


Fig. 11. Galley hull imported in Free!ship.

The program immediately identified the waterline based on the centerline and the ship's shape, and as to be expected, the program-generated waterline did not take into account the absent outrigger and the superstructure of the vessel. The Free!ship program allowed an additional waterline to be created and, like the waterline created in Rhinoceros, it was placed 2 feet below the top of the gunwale amidships (Fig. 12).

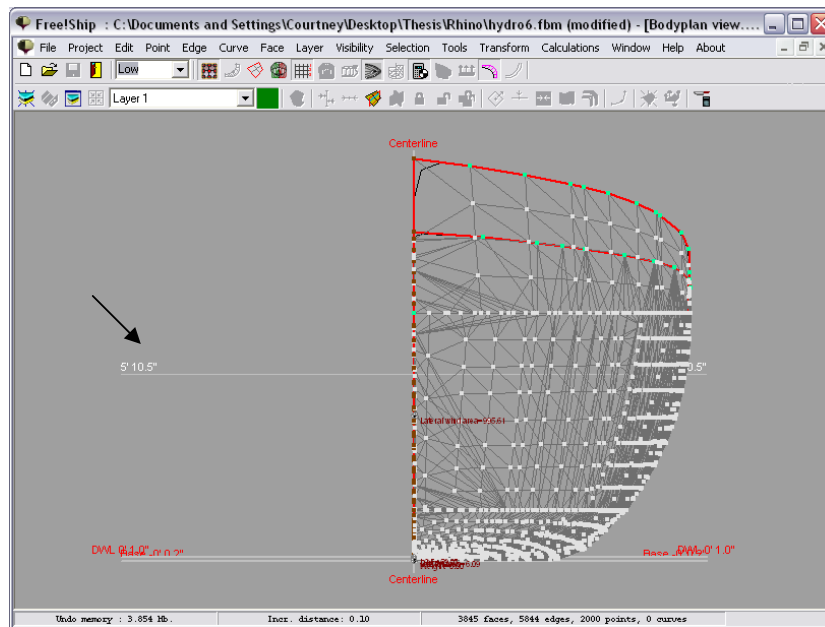


Fig. 12. Galley breadth with arrow at added waterline.

At this point, the hydrostatics data were processed in Free!ship and these results are displayed in Table 4.²²⁶ The waterline information is based on the newly added waterline. Additional information generated from the program can be found in Appendix A.

²²⁶ The program allowed the user to choose the water density. I used the default of 65.016 lbs/cubed foot.

Table 4. Results of hydrostatics calculated in Free!ship with Rhinoceros results

	Free!ship hydrostatics- using new waterline		Rhinoceros hydrostatics	
	Imperial	Metric	Imperial	Metric
Volume displacement	7419.500 cubic feet	210.1 cubic meters	7736.96 cubic feet	219.1 cubic meters
Longitudinal center of buoyancy	58.523 feet	17.84 meters	-0.0218429, 0.0391434, 3.22966	-0.006658, 0.01193, 0.9844
Wetted surface area	2362.3 feet square	219.4 meters square	2410.53 feet square	734.7 meters square
Waterline length	116.774 feet	3.307 meters	116.667 feet	35.57 meters
Maximum waterline beam	17.118 feet	5.218 meters	17.347 feet	5.287 meters
Water plane area	1651.6 cubic feet	46.78 cubic meters	1658.39 cubic feet	46.96 cubic meters
Center of floatation	58.636	17.87	-0.043451, -0.271897, 5.785	-0.01324, -0.08287, 1.763

When comparing the two programs, the results are relatively similar, except for the Longitudinal Center of Buoyancy and Center of Flotation, which were generated in different formats. As for the rest of the calculations, there is less than a 4 percent difference between the numbers. This discrepancy can likely be attributed to the method in which the program calculates the hydrostatics from the drafted points, such as the quantity of points used in the calculation, the accuracy of the surface it generated, or the difference between using the whole vessel in Rhinoceros versus half of the vessel in Free!ship. This small discrepancy should not greatly impact comparing the volumes and areas with the historical documentation.

Prior to comparing these data with the historical documentation, we need to cross-check the two sets of data. Looking closely at both sets of numbers, the first items to note are the length of the waterline and the waterline beam length. Both of these numbers appeared incredibly close to the overall length and breadth of the ship, but this is not too surprising. It is logical that these numbers are close to the maximum length and breadth because most of the curvature is found in the bottom third of the ship, and because the waterline is located close to the deck of the ship.

The next calculation examined was the water displacement since it is important in helping to figure out the capacity of the vessel, specifically the cargo capacity. The displaced volumes calculated are 7,419.5 and 7736.96 cubic feet, which equals approximately 210 and 219.1 cubic meters, respectively. Alertz notes that depending on

draught, the galley of Flanders had a displacement between 292 and 356 cubic meters.²²⁷ Unfortunately, no historical records are known that specifically state the capacity of the galley of Flanders, including within treatises. The closest information dictating capacity is the maximum limit set by the Senate. In the early 1300s the merchant galleys were not allowed to exceed a cargo capacity of 50 metric tons.²²⁸ The Senate's regulation caps the galley of Flanders to 110 metric tons in 1320, and 140 metric tons in 1356.²²⁹ The latter was still the regulation in 1420; however, the Senate complained that the galleys were being built with capacities as high as 500 or 600 *milliaria* (260 to 300 tons), resulting in a large, unwieldy vessel.²³⁰ A 1440 law capped the merchant galleys at 400 to 440 *milliaria* (200 to 220 tons) below deck.

The Senate's regulations limit the galley's capacity in weight (converted to metric tons) and the capacities generated in the modeling programs present the information in volume (cubic meters). This appears to be comparing two different measurement units; however, Lane has found that both weight and volume were used for measuring capacity throughout Venice's trading history.²³¹ Based on his studies of tonnage calculations in Venice, Lane calculates 2,240 pounds (one metric ton) is equivalent to 1.7 cubic

²²⁷ Alertz 1995, 158.

²²⁸ Lane 1964, 230.

²²⁹ Supra n. 228.

²³⁰ Lane 1934, 15. Two *milliaria* was equal to one metric ton. Lane (1934b, 172) notes that the galleys had become so large that they were unable to be operated under oar, including in ports.

²³¹ Lane 1964, 222, 218. He warns that in historical texts it can be hard to determine whether the tonnage is referring to the maximum tonnage, the capacity measured in tons, or the ship's registered tonnage, which was a calculation based on the ship's size and not cargo.

meters.²³² Using this conversion, the 3-D model has a capacity of 124 metric tons in Free!ship and 129 metric tons in Rhinoceros, both of which are comparable to the legal restrictions dating to the period.²³³ Even though the 3-D galley of Flanders model is a single example and there are many factors to consider, the 3-D programs appear to be fairly reliable tools for calculating water displacement and conceivably the hull's cargo capacity.

One potential use for calculating a ship's capacity would be to determine the quantity of sellable cargo brought aboard the vessel and where was it stored.²³⁴ If the amount of supplies needed for the voyage and how much space they took up is known, this information could be subtracted from the vessel's capacity and the space for sellable wares could be determined. From the Michael of Rhodes book, we know the galley of Flanders carried one main mast, one lateen yard, one middle mast, one middle lateen yard, one boat, one skiff, five anchors, at least a dozen lengths of rope of different weights and lengths, several tackles and pulleys of different sizes.²³⁵ And while the weight or lengths are given for most of these items, the space they took up, their location

²³² Lane 1934, 246. Today, 2,240 pounds are still equal to one ton (or long ton), but the volume is more difficult to gauge because different sources range from 0.99 to 2.83 cubic meters (35 to 100 cubic feet). Volume and weight conversions depend on density. One ton of cotton would take up much more space than one tone of spices. See Lane's 1964 article for more information on the calculations of tonnage in Medieval Europe.

²³³ Alertz's water displacement equals 171.8 to 209.4 metric tons

²³⁴ Where the equipment was stored appears to be inconsequential information, except that the sellable merchandise would likely be stored in the hull, where it could be protected from weather, and the equipment could be stored, either on deck or in the hull. Depending on how much of the ship's equipment was stored below deck affects how much merchandise could fit in the hold.

²³⁵ These items are listed as equipment, along with oars, weapons, food, and water.

on the ship, and how they were stored is unknown, thus making this task unrealistic to attempt, at this time.

Lane has calculated the legal capacity in 1420 for cargo below deck for the galley of Flanders is 140 metric tons and the total cargo was 170 metric tons, which included storage on the deck.²³⁶ Even though Senate prohibited storage of cargo and personal gear on the deck, this was not enforced and often the rowers' trunks and personal sellable wares were kept on deck.²³⁷ With the personal gear on the deck, Lane interprets the merchant galley hold to be broken down into eight compartments, based on information in Arsenal documents (Fig. 13).²³⁸

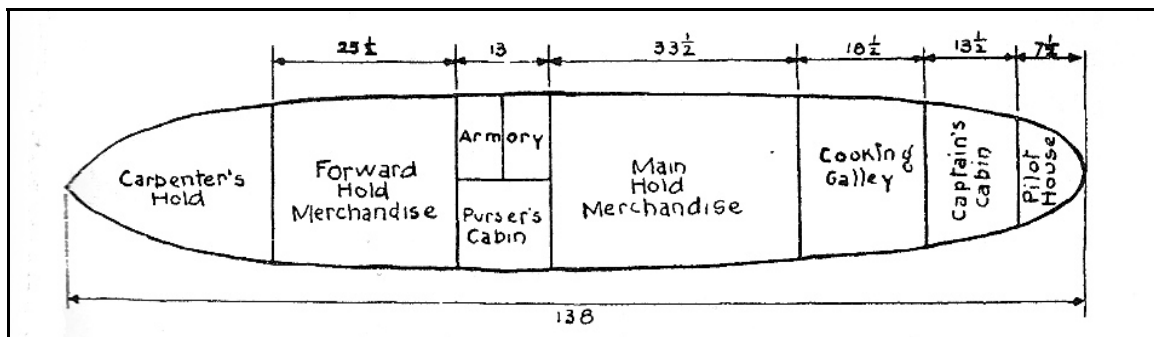


Fig. 13. Lane's layout of a merchant galley hold.²³⁹

²³⁶ Lane 1964, 231.

²³⁷ Alertz, 1995, 158; Lane 1966, 7.

²³⁸ Lane 1934, 25.

²³⁹ Lane 1934, 25, Fig. VII.

Lane's drawing depicts a longer galley than the galley of Flanders, but the general layout indicates that approximately 42 percent of the area of available floor space below deck would be devoted to sellable wares. The cargo bays flank the midships, where the breadth was the widest and where the ship was most stable. Using this percentage as a model, approximately 50 feet of the galley of Flanders's length would hold merchandise. This length was applied to the 3-D model of the hull and the program calculated a volume of 172 cubic meters for this space. If Lane's diagram is accurate, then a large amount of space is devoted to the commercial cargo, and not very much space is needed for the supplies and equipment of the vessel.

There are numerous factors to consider when discussing the loading of the galley, such as the wares being carried aboard (light versus heavy) and how many extra men were brought on board to defend the ship. In all likelihood, each captain had the exact calculations of their vessel's potential cargo capacity for a specific voyage.²⁴⁰ Since ship loading was a delicate task and different for each voyage, it is not surprising that there is so little information from the period on how it was accomplished.

Here, the hold of the galley of Flanders was generated in Rhinoceros, and both it and Free!ship were able to provide reliable information about the probable capacity of the vessel. The tools used in this chapter can potentially be used not only in creating a 3-D replica of a vessel, but also can be used in helping to understand the volume and capacity

²⁴⁰ Lane 1964, 221.

of that vessel. Although the cargo capacity of the galley of Flanders and how the cargo was loaded could not be determined at this time, the data gathered above and the use of such tools as Rhinoceros and Free!ship, such information may one day be learned and used for further scholarship.

CHAPTER V

CONCLUSIONS

Using those resources that have survived over time, such as paintings, drawings, and written texts, the lack of physical shipwrecks from an archaeological context does not necessarily limit nautical research. In this case study on the galley of Flanders, the Michael of Rhodes book and the book of Zorzi Trombetta da Modone, from the Late Middle Ages were examined in detail for information on the Venetian galleys of their time. The *Fabrica di Galere* was mentioned briefly as a supplement to the Michael of Rhodes text. After recognizing the limitations of these documents and identifying potential flaws of each, the treatises were used to try to understand how 15th century galleys were conceived and to evaluate the problems related to the development of a tentative model. Ultimately, analysis of the Michael of Rhodes book and the book of Zorzi Trombetta da Modone allowed me to develop a tentative 3-D model and analyze its basic dimensions. The stated goal of this thesis is to achieve a better understanding of the dimensional characteristics of a galley through the development and analysis of a computer generated 3-D model.

In order to appreciate the context of the galley of Flanders, I began this thesis by discussing the history of Venice through the High to Late Middle Ages. The city's location, government, and organization of commercial endeavors lead to its success as a trade empire. Venice had established seven routes that were traveled annually and the Venetians built vessels specific to each route. The longest route, the one to Flanders,

relied on both round ships and galleys carrying both bulk and luxury goods, respectively. The first documented voyage of the galley of Flanders was in 1315 and the last recorded was in 1532.

Keeping in mind the limitations and potential inaccuracies of using treatises, I examined the book of Michael of Rhodes, the book of Zorzi Trombetta da Modone, and the *Fabrica di Galere*, specifically looking for information on the galley of Flanders. After translating each of them, I compared their specifications of the vessel. Ultimately, the purpose of studying the documents was to determine if they had enough information to generate a 3-D model.

The first conclusion to be drawn from this study is the similarity between the Michael of Rhodes book and the *Fabrica di Galere*. The *Fabrica di Galere* dating to the mid-15th century, attests to its relevance since it was created one century after the potential original, the Michael of Rhodes book, was written. Zorzi Trombetta's book was also analyzed, and although it was not as useful, the information it conveys regarding the shape of the hull bottoms of these galleys is extremely important. It will be used at a later stage, when the plausibility of this model is fully established, to refine the proposed hull shape. In spite of the problems between the general measurements given and the ratio rules recommended, the relevance of this manuscript stands.

The second important conclusion of this project is that in spite of gaps in the data, the best process for understanding hull shape is to develop and analyze models in a converging, iterative process, as shown by the Pepper Wreck project in the Ship Reconstruction Laboratory at Texas A&M University.²⁴¹ Enough information was found in the Michael of Rhodes text that a 3-D model could be created; however, some assumptions had to be made in developing the present model. For example, several pages in the Michael of Rhodes' book left spaces for measurements that were never written. This treatise also did not include measurements such as the sided and molded dimensions of the keel, the room and space, or the draft, to name only few. But my model does not pretend to be more than a step toward a better understanding of these fascinating ships.

As previously mentioned the galley of Flanders was chosen as the subject of this reconstruction because it has a fair amount of information written about it, when compared to other vessels in the same treatises. This being said, there are still vital pieces of information missing regarding the ship's construction that would help recreate the vessel, and I acknowledge that future research will help identify the most important questions to be addressed.

The Michael of Rhodes book describes a galley (in Venetian units of measurement) that is 118.50 feet long, 17.50 feet wide and 7.88 feet deep at midships. The rake of the

²⁴¹ Castro and Fonseca, 2006.

sternpost is 10.50 feet and its rise is 13.00 feet. The rake of the sternpost is 10.50 feet, with a rise of 10.50 feet. The rake and rise measurements are accompanied by illustrations showing the curvatures. The midship cross-section is also illustrated and provides dimensions to establish the curvature of the frames. In the document it is noted that there are 88 whole frames, that the aft tail frame is 9.25 feet from where the keel meets the sternpost, and that the fore tail frame is 7.13 feet from where the keel meets the sternpost.

Once the dimensions of the vessel were established, a lines drawing of the galley was created. Calculations that were not found in the treatise were either deduced using the known calculations or they were approximated from measurements taken from the hull remains of the Lake Garda war galley (1509). An example of a deduced measurement comes from calculating the keel length by subtracting the length rake of the stem and the stern from the overall length of the vessel. The lines drawing was then converted into a 3-D model in the Rhinoceros program by rotating and matching the plan, profile, and breadth views of the galley. Once the framework was in place, the surface of the hull planking, the frames and the keel were created.

From the completed 3-D model, hydrostatics were calculated using the Rhinoceros software. The most important factor in calculating the hydrostatics was establishing a waterline, or the lowest point at which the loaded vessel sits in the water. The texts do not mention the waterline, since it is likely that this was not a written calculation. The

shipwrights would know from experience how deep the vessel sat in the water. Based on Venetian law, the freeboard of the galley was 2 feet minimum, so the waterline was established on the digital ship at 5.785 feet below the gunwale (height at midships, 7.785 less 2 feet).

After transferring the hull data from Rhinoceros to Free!ship and setting the waterline, I was able to calculate the hydrostatics. Hydrostatic data include but are not limited to: volume displacement, center of buoyancy, wetted surface area, water plane area, and center of floatation. For the purposes of this study, the volume displacement is the most relevant figure to look at in both programs, since it helps in determining the interior volume of the hull, ergo the amount of room for cargo. The volume displacement was calculated to be 219.1 m³ and 210.1 m³ by Rhinoceros and Free!ship, respectively. Because 2,240 pounds (one metric ton) is equivalent to 1.7 m³, my galley of Flanders has a capacity of 124 to 129 metric tons.

Being that the treatises did not have any capacity information, it was difficult to determine if the calculated volumes from the 3-D models were reasonable. Venetian governmental records indicate that Senate regulations capped the galley of Flanders at 140 metric tons in 1356, but that limit was raised to 200 - 220 tons in 1440. The capacity of the vessel in the 3-D modeling programs places the capacity well below these regulations. The difference between the Senate's 1440 regulation and the calculated capacities may be attributed to minor errors in the 3-D building of the ship, or it may be

that the measurements in the Michael of Rhodes book were for a ship that was smaller than the regulation cap. However, these differences are a result of the following assumptions: (a) Lane's conversion is correct, (b) the treatise is written about a galley dating to 1356 or 1440 (not prior), (c) there is no error in dimensions given in the treatise, and (d) the limited information on the Senate regulations is also correct. In spite of these, the correlation of hydrostatic data with historical documents demonstrate that 3-D models of vessels can be effectively generated and analyzed using even small amounts of data.

Recommendations

This case study explored one aspect of shipbuilding in conjunction with 3-D modeling. Shipbuilding treatises are a valuable and sometimes the only tool available to help understand how ships were built and maneuvered, provided one is cautious when using them. The conversion of the galley of Flanders's dimensions from the Michael of Rhodes book into a 3-D model is an example of the potential integration of treatises and 3-D modeling programs. They can provide a better understanding of vessels where archaeological evidence is sparse. In addition, looking at the capacity is also just the beginning, as these programs can help shed light on how the vessels maneuvered, reacted to environmental conditions, and even how they sank. At the height of the empire the Venetians likely saw the potential for overseas trade as limitless; today's nautical scholars should see the potential for studying Venetian vessels as equally limitless.

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APPENDIX A

TABLE A1: HYDROSTATIC CALCULATIONS GENERATED BY FREE!SHIP

Project : Galley of Flanders
 Design length : 0.101 ft
 Length over all : 118.47 ft
 Design beam : 0.102 ft
 Beam over all : 17.459 ft
 Design draft : 0.102 ft
 Midship location : 0.050 ft
 Water density : 65.016 lbs/ft³
 Appendage coefficient : 1.0000

NOTE 1: Draft (and all other vertical heights) is measured above the lowest point of the hull ($Z = -0.021$)

NOTE 2: All calculated coefficients based on actual dimensions of submerged body.

Note 3: The bulb characteristics is calcs right, if F.P. is through point of intersection forward line with DWL.

Key to Table A1

Lwl : Length on waterline

Bwl : Beam on waterline

Volume : Displaced volume

Displ. : Displacement

LCB : Longitudinal center of buoyancy, measured from the aft perpendicular at $X=0.0$

VCB : Vertical center of buoyancy, measured from the lowest point of the hull

Cb : Block coefficient

Am : Midship section area

Cm : Midship coefficient

Aw : Waterplane area

Cw : Waterplane coefficient

LCF : Waterplane center of floatation

Cp : Prismatic coefficient

S : Wetted surface area

KMt : Vertical of transverse metacenter

KMl : Longitudinal transverse metacenter

Table A1

Draft	Trim	Lwl	Bwl	Volume	Displ.	LCB	VCB	Cb	Am	Cm	Aw	Cw	LCF	Cp	S	KMt	KMI
ft	Ft	Ft	Ft	ft^3	tons	ft	ft	[-]	ft^2	[-]	Ft^2	[-]	ft	[-]	ft^2	ft	ft
0	0	0	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.1	0	98.14 9	9.13	16.30 5	0.473	60.90 1	0.074	0.182	0	0	386.8 7	0.431 7	59.31 7	0	387.1 7	97.47 2	7099. 6
0.2	0	102.6 52	9.865	65.88 5	1.912	59.21 5	0.134	0.325 3	0	0	580.7 9	0.573 5	58.40 2	0	583.7 8	48.17 8	3683. 9
0.3	0	103.7 94	10.30 4	129.9	3.77	58.78 1	0.192	0.404 9	0	0	691.8 3	0.646 9	58.32 1	0	698.2 6	33.96 3	2609. 3
0.4	0	104.8 24	10.77 5	203.4	5.904	58.60 4	0.249	0.450 2	0	0	774.3 1	0.685 6	58.3	0	783.7 5	27.22 9	2062. 7
0.5	0	105.6 62	11.09 2	284.1 3	8.247	58.52 3	0.306	0.484 9	0	0	837.5 6	0.714 7	58.34 1	0	851.3 4	23.00 4	1712. 2
0.6	0	106.3 67	11.31	370.5 7	10.75 6	58.48 6	0.363	0.513 4	0	0	889.7 8	0.739 6	58.38 9	0	908.5 1	20.16 3	1467. 6
0.7	0	106.9 63	11.53	461.8 6	13.40 5	58.47 3	0.42	0.535	0	0	934.9 1	0.758 1	58.45 1	0	959.1 3	18.14 3	1286. 2
0.8	0	107.5 25	11.74 9	557.3 5	16.17 7	58.47 4	0.477	0.551 5	0	0	974.5 1	0.771 4	58.51 9	0	1004. 8	16.59 4	1147
0.9	0	108.0 46	11.96 5	656.6 7	19.06	58.48 6	0.533	0.564 4	0	0	1011. 3	0.782 3	58.58 1	0	1048. 1	15.43 6	1037. 5
1	0	108.5 29	12.17 6	759.5 6	22.04 6	58.50 3	0.59	0.574 8	0	0	1046. 2	0.791 7	58.64 7	0	1089. 7	14.54 1	949.4 9
1.1	0	108.9 69	12.37 1	865.8 5	25.13 1	58.52 6	0.646	0.583 9	0	0	1079. 2	0.800 6	58.72 1	0	1129. 8	13.82 2	877.1 9
1.2	0	109.3 67	12.56 3	975.3 6	28.31	58.55 2	0.703	0.591 6	0	0	1110. 8	0.808 5	58.80 2	0	1168. 8	13.24 3	816.1 6
1.3	0	109.7 35	12.75 5	1088	31.57 8	58.58 2	0.759	0.598	0	0	1141. 3	0.815 5	58.88 9	0	1206. 9	12.77 3	764.1
1.4	0	110.0 59	12.93 5	1203. 5	34.93 2	58.61 5	0.816	0.603 8	0	0	1169. 3	0.821 3	58.94 8	0	1243. 3	12.33	718.8 7

Table 1A Continued

Draft	Trim	Lwl	Bwl	Volume	Displ.	LCB	VCB	Cb	Am	Cm	Aw	Cw	LCF	Cp	S	KMt	KMl
ft	Ft	Ft	Ft	ft^3	tons	ft	ft	[-]	ft^2	[-]	Ft^2	[-]	ft	[-]	ft^2	ft	ft
1.5	0	110.3 64	13.16 4	1321. 6	38.35 9	58.64 2	0.873	0.606 4	0	0	1190. 7	0.819 5	58.85 8	0	1274. 9	11.84 3	673.2 1
1.6	0	110.6 42	13.37 8	1441. 6	41.84 3	58.65 4	0.929	0.608 7	0	0	1209. 5	0.817 1	58.73 7	0	1304. 6	11.40 4	631.1 1
1.7	0	110.9 11	13.52 1	1563. 3	45.37 5	58.65 9	0.985	0.613 2	0	0	1224. 4	0.816 5	58.69 7	0	1331. 9	10.96 5	591.5 8
1.8	0	111.1 77	13.65	1686. 5	48.94 9	58.66	1.041	0.617 4	0	0	1238. 3	0.816	58.67 3	0	1358. 6	10.57 8	556.4 6
1.9	0	111.4 31	13.77 6	1811	52.56 4	58.66 1	1.097	0.620 9	0	0	1251. 9	0.815 6	58.65 2	0	1385. 2	10.24 3	525.5 9
2	0	111.6 76	13.91 2	1936. 8	56.21 6	58.66	1.152	0.623 3	0	0	1264. 9	0.814 1	58.64 2	0	1411. 4	9.949	497.8 7
2.1	0	111.9 49	14.05 9	2063. 9	59.90 6	58.65 8	1.208	0.624 5	0	0	1277. 5	0.811 7	58.63 2	0	1437. 6	9.691	473.1 4
2.2	0	112.1 98	14.2	2192. 3	63.63 2	58.65 6	1.263	0.625 5	0	0	1289. 9	0.809 6	58.62	0	1463. 7	9.463	450.9 3
2.3	0	112.4 04	14.33 7	2321. 9	67.39 3	58.65 4	1.318	0.626 4	0	0	1301. 8	0.807 8	58.60 9	0	1489. 7	9.259	430.7 6
2.4	0	112.6 02	14.46 9	2452. 6	71.18 7	58.65 1	1.373	0.627 2	0	0	1312. 6	0.805 6	58.58 5	0	1515. 2	9.064	412.0 9
2.5	0	112.7 91	14.59 3	2584. 4	75.01 3	58.64 7	1.428	0.628 1	0	0	1323. 1	0.803 8	58.55 7	0	1540. 6	8.889	395
2.6	0	112.9 81	14.71 6	2717. 3	78.86 8	58.64 2	1.483	0.628 6	0	0	1333. 4	0.802	58.52 7	0	1566	8.733	379.3 9
2.7	0	113.1 59	14.83 7	2851. 1	82.75 3	58.63 6	1.537	0.629	0	0	1343. 4	0.800 2	58.50 2	0	1591. 2	8.592	365.0 2
2.8	0	113.3 27	14.95 3	2985. 9	86.66 6	58.62 9	1.592	0.629 3	0	0	1353. 2	0.798 6	58.47 9	0	1616. 4	8.464	351.7 7
2.9	0	113.4 95	15.06 7	3121. 8	90.60 8	58.62 2	1.647	0.629 5	0	0	1362. 9	0.797	58.45 8	0	1641. 6	8.35	339.5 8
3	0	113.6 54	15.18 2	3258. 5	94.57 8	58.61 5	1.702	0.629 5	0	0	1372. 5	0.795 4	58.43 8	0	1666. 8	8.249	328.2 7

Table 1A Continued

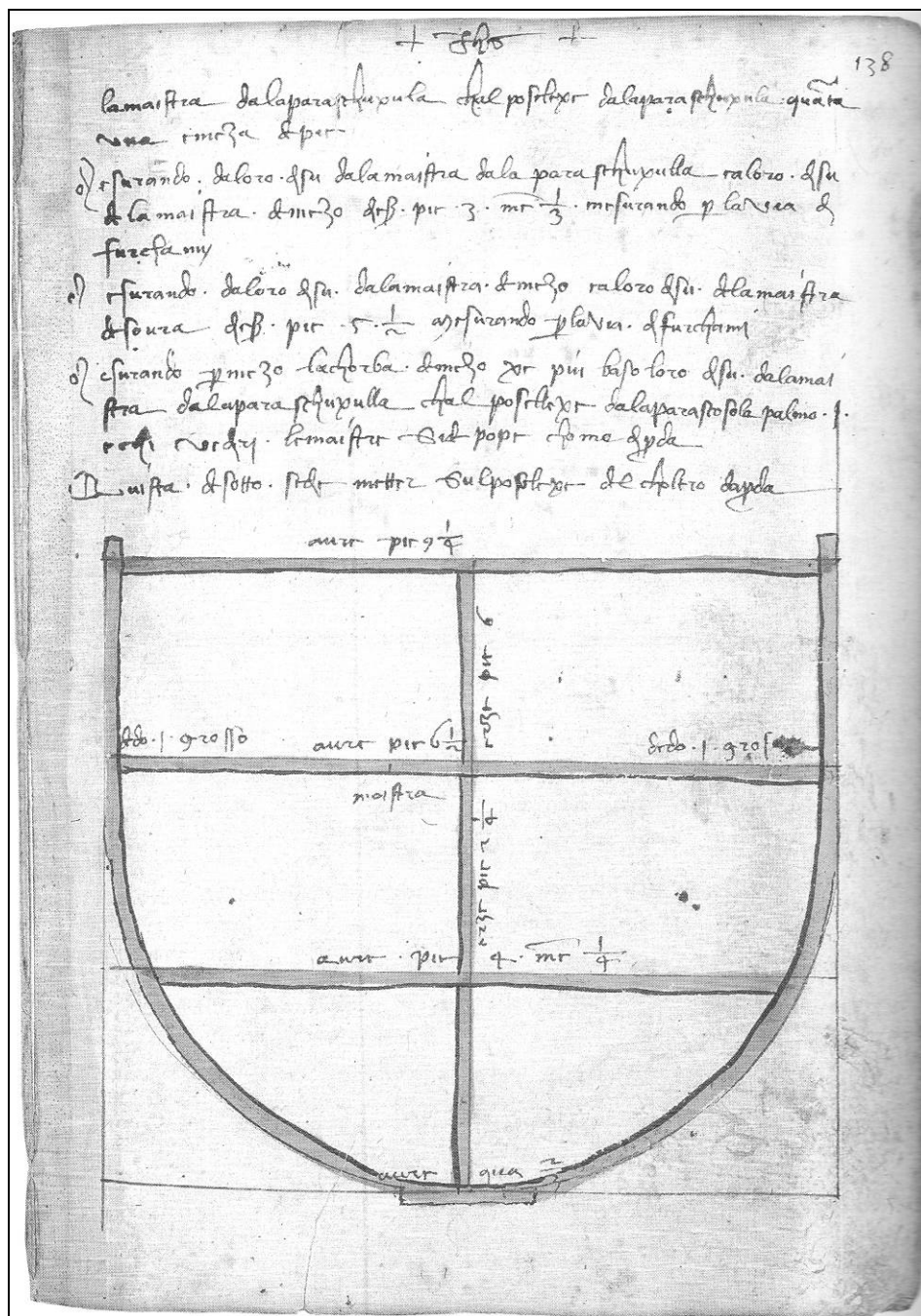
Draft	Trim	Lwl	Bwl	Volume	Displ.	LCB	VCB	Cb	Am	Cm	Aw	Cw	LCF	Cp	S	KMt	KMl
ft	Ft	Ft	Ft	ft^3	tons	ft	ft	[-]	ft^2	[-]	Ft^2	[-]	ft	[-]	ft^2	ft	ft
3.1	0	113.806	15.288	3396.3	98.575	58.608	1.756	0.6297	0	0	1381.7	0.7941	58.424	0	1691.9	8.155	317.7
3.2	0	113.957	15.391	3534.9	102.6	58.6	1.811	0.6298	0	0	1390.9	0.793	58.412	0	1716.9	8.07	307.89
3.3	0	114.103	15.494	3674.4	106.65	58.593	1.866	0.6298	0	0	1399.9	0.7918	58.401	0	1742	7.995	298.74
3.4	0	114.246	15.594	3814.8	110.73	58.586	1.92	0.6298	0	0	1408.8	0.7908	58.393	0	1767	7.928	290.15
3.5	0	114.387	15.685	3956.2	114.83	58.579	1.975	0.63	0	0	1417.5	0.79	58.388	0	1792	7.865	282.08
3.6	0	114.521	15.777	4098.4	118.95	58.572	2.03	0.6301	0	0	1426.1	0.7893	58.385	0	1816.9	7.809	274.52
3.7	0	114.65	15.869	4241.4	123.11	58.565	2.084	0.6301	0	0	1434.6	0.7885	58.381	0	1841.9	7.76	267.4
3.8	0	114.778	15.952	4385.3	127.28	58.559	2.139	0.6303	0	0	1442.9	0.788	58.381	0	1866.8	7.715	260.66
3.9	0	114.903	16.033	4530	131.48	58.554	2.194	0.6305	0	0	1451	0.7876	58.384	0	1891.7	7.674	254.3
4	0	115.024	16.114	4675.5	135.7	58.548	2.248	0.6306	0	0	1459.1	0.7872	58.386	0	1916.6	7.638	248.29
4.1	0	115.144	16.195	4821.8	139.95	58.543	2.303	0.6307	0	0	1467.2	0.7868	58.39	0	1941.5	7.606	242.61
4.2	0	115.263	16.269	4968.9	144.22	58.539	2.358	0.6309	0	0	1474.9	0.7865	58.397	0	1966.3	7.577	237.18
4.3	0	115.376	16.338	5116.8	148.51	58.535	2.412	0.6313	0	0	1482.5	0.7865	58.405	0	1991.2	7.55	232.03
4.4	0	115.486	16.407	5265.4	152.83	58.532	2.467	0.6316	0	0	1490.1	0.7865	58.412	0	2016	7.528	227.13
4.5	0	115.596	16.476	5414.8	157.16	58.528	2.522	0.6318	0	0	1497.6	0.7863	58.42	0	2040.8	7.509	222.46
4.6	0	115.701	16.536	5564.9	161.52	58.525	2.576	0.6323	0	0	1504.8	0.7865	58.431	0	2065.6	7.491	217.98

Table 1A Continued

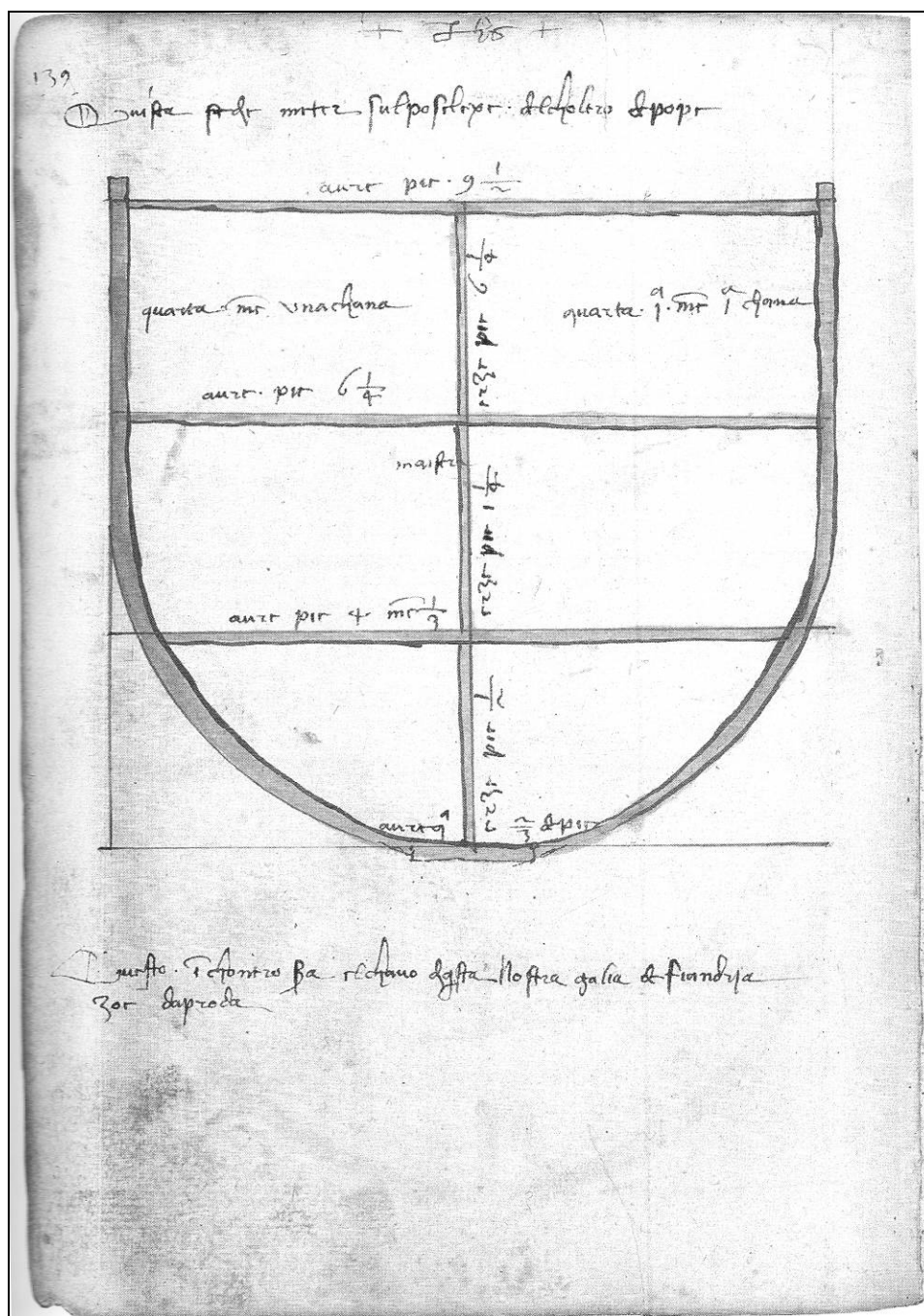
Draft	Trim	Lwl	Bwl	Volume	Displ.	LCB	VCB	Cb	Am	Cm	Aw	Cw	LCF	Cp	S	KMt	KMl
ft	Ft	Ft	Ft	ft^3	tons	ft	ft	[-]	ft^2	[-]	Ft^2	[-]	ft	[-]	ft^2	ft	ft
4.7	0	115.8 02	16.59 6	5715. 8	165.9	58.52 3	2.631	0.632 8	0	0	1512	0.786 7	58.44 3	0	2090. 3	7.476	213.7 1
4.8	0	115.9 02	16.65 5	5867. 3	170.3	58.52 1	2.686	0.633 2	0	0	1518. 9	0.786 9	58.45 2	0	2115. 1	7.463	209.6
4.9	0	116.0 01	16.71 4	6019. 5	174.7 2	58.52	2.741	0.633 6	0	0	1525. 9	0.787	58.46 2	0	2139. 8	7.453	205.6 8
5	0	116.0 97	16.76 7	6172. 5	179.1 6	58.51 8	2.795	0.634 2	0	0	1532. 7	0.787 4	58.47 5	0	2164. 5	7.444	201.9 1
5.1	0	116.1 9	16.81 7	6326. 1	183.6 1	58.51 7	2.85	0.634 8	0	0	1539. 3	0.787 8	58.49	0	2189. 2	7.437	198.3
5.2	0	116.2 82	16.86 6	6480. 4	188.0 9	58.51 7	2.905	0.635 4	0	0	1545. 9	0.788 2	58.50 5	0	2214	7.433	194.8 5
5.3	0	116.3 69	16.91 6	6635. 3	192.5 9	58.51 7	2.96	0.636	0	0	1552. 6	0.788 7	58.52 2	0	2238. 7	7.431	191.5 4
5.4	0	116.4 55	16.96 2	6790. 9	197.1	58.51 7	3.014	0.636 7	0	0	1559	0.789 3	58.54 1	0	2263. 5	7.431	188.3 4
5.5	0	116.5 37	17.00 1	6947. 1	201.6 4	58.51 8	3.069	0.637 5	0	0	1565. 3	0.79	58.56 3	0	2288. 2	7.431	185.2 6
5.6	0	116.6 17	17.04 1	7103. 9	206.1 9	58.51 9	3.124	0.638 3	0	0	1571. 5	0.790 8	58.58 7	0	2312. 9	7.433	182.3 1
5.7	0	116.6 97	17.08	7261. 4	210.7 6	58.52 1	3.179	0.639 1	0	0	1577. 8	0.791 6	58.61	0	2337. 6	7.437	179.4 6
5.8	0	116.7 74	17.11 8	7419. 5	215.3 5	58.52 3	3.233	0.64	0	0	1583. 9	0.792 4	58.63 6	0	2362. 3	7.443	176.7 2

APPENDIX B

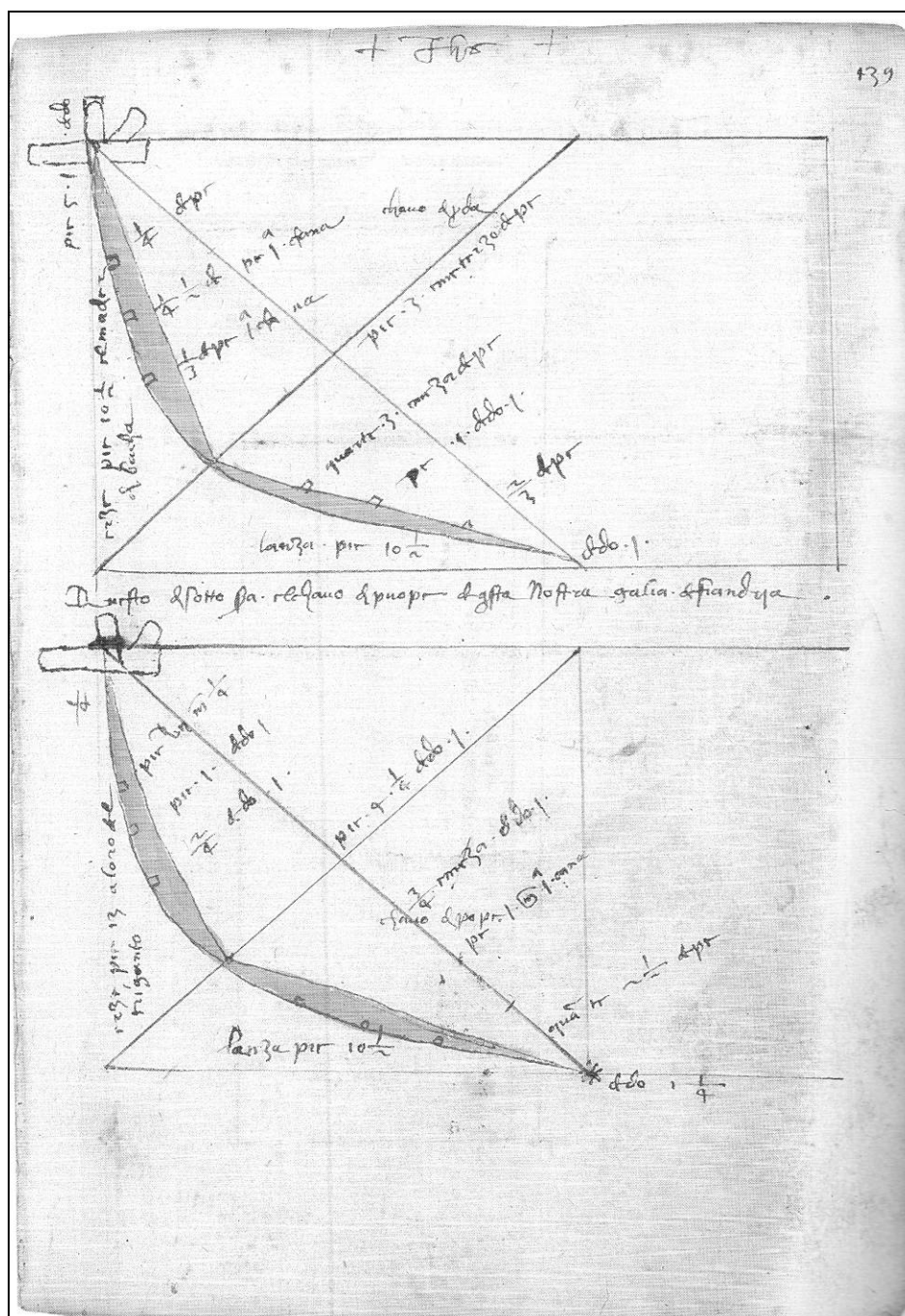
FOLIO 138b, 139a, and 139b (copies from McGee 2009, 224, 225, and 226).



Folio 138b.



Folio 139a.



Folio 139b

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Professional Experience

2010- present	Staff Archaeologist Far Western Anthropological Research Group, Inc, Henderson, NV
2008-2010 2001-2005	Staff Archaeologist SWCA Environmental Consultants Denver, CO
Summer 2006, 2007, and 2009	Student Archaeologist Excavations at Roman shipwreck Kızılburun Turkey
2005-2007	INA Quarterly Editor Institute of Nautical Archaeology College Station, TX
1999- 2000	Conservation Assistant Denver Museum of Nature and Science Denver, CO